ECOLOGY OF UPPER KLAMATH LAKE SHORTNOSE AND LOST RIVER SUCKERS

3. Annual survey of abundance and distribution of age 0 shortnose and Lost River suckers in Upper Klamath Lake

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ANNUAL REPORT (partial)

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INTRODUCTION AND OVERVIEW

The Klamath Basin's endangered suckers, *Chasmistes brevirostris* Cope, 1879 (shortnose sucker, SNS), and *Deltistes luxatus* (Cope, 1879) (Lost River sucker, LRS) were listed based, in part, on the perception that recruitment had failed for many years. Our sampling surveys have supported the notion that recruitment failure was an important problem and indicated the number of survivors in a year class can differ greatly. Because recruitment failure or variation can be caused by very small changes in mortality rates, growth rates, or stage durations in the early part of life (Houde 1987), we have expended our efforts on the first year of life of Upper Klamath Lake suckers.

Our approach to year class assessment in 1999 was identical to 1997 and 1998, and nearly identical to 1995 and 1996. We conducted 6 surveys every third week with a larval trawl from April – July to assess early season larval sucker abundance. Four beach seine surveys were conducted every third week from June – August to assess mid season juvenile sucker abundance. The last 3 larval trawl surveys were concurrent with the first 3 beach seine surveys. This multiple gear strategy ensured we remained effective on multiple cohorts. Three concurrent cast net/otter trawl surveys were conducted every third week from late August – early October to assess late summer and early fall juvenile sucker abundance. Cast net surveys assessed shoreline abundance while concurrent otter trawl surveys assessed offshore abundance. Spring random otter trawl surveys were conducted in April to assess overwinter survival of the 1998 year class (now age 1). Water quality parameters including dissolved oxygen, pH, conductivity, and water temperature were measured for each fish sample.

METHODS

Larval sampling

Larval trawl sampling in 1999 was conducted every third week on April 6-7, April 27-28, May 18-19, June 8-9, June 29-30, and July 20-21. Two samples were collected from 10 fixed sites in Upper Klamath Lake and 5 fixed sites in Agency Lake (Figure 1). The larval trawl has a 0.8 x 1.5 m opening with 2.5 m of 1000 micron Nitex mesh netting. The larval trawl is mounted on an aluminum frame with runners, similar to that described by LaBolle et al. (1985), and was set 2-12 m (avg. 6.5 m) from shore by wading out and placing the trawl in water 1 m deep. The trawl was then pulled to shore with ropes. If vegetated and nonvegetated habitats were available at a site, one sample was collected from each. Because of disturbance to the area when setting the larval trawl, a minimum of 10-15 minutes was waited before pulling to shore. Thirty samples were collected each survey for a total of 180 samples.

Beach seine

Beach seine sampling in 1999 was conducted every third week on June 8-9, June 29-30, July 20-21, and August 9-10. Two samples were collected from each of 10 fixed sites in Upper Klamath Lake and 5 fixed sites in Agency lake—the same sites as the larval trawl sampling. The beach seine was 6.1 m in length with a 2 x 2 x 2 m bag and constructed with 4.8 mm bar mesh. Each sample was collected with one person remaining on shore and the other walking perpendicular into the water while unrolling the seine until the end of the seine was reached. The offshore person then pulled the net to shore in a ¼-circle arc with the shoreline person remaining stationary. Samples were normally collected from waters less than 1.5 m deep and over unvegetated or sparsely vegetated shorelines. Thirty samples were collected each survey for a total of 120 samples.

Cast net

Cast net sampling in 1999 was conducted every third week on August 23-25, September 13-15, and October 4-6. The cast net was a 5 m diameter multifilament net with 6.3 mm bar mesh. Sampling protocol followed a stratified random design based on 8 different shoreline substrate types (Table 1). The entire Upper Klamath Lake shoreline was mapped with hand-held GPS units in 1994 when water levels were at record lows, thus exposing the shoreline substrates and allowing us the opportunity to collect the necessary data to construct a shoreline substrate map that our cast net sampling is based upon. All cast net samples were normally collected within 10 m of the shoreline in water depths normally ranging from 0.5 – 1.0 m, and typically not exceeding 1.5 m. Cast net samples were collected from nonvegetated or sparsely vegetated locations and were collected along the edge of the vegetation wherever the shoreline was vegetated. Prior to each cast net survey, sampling sites were randomly selected within each substrate category. Latitude and longitude coordinates for each site were then mapped in GIS software. A hand-held GPS unit and the maps were used to locate each site, within the error limits of uncorrected GPS points. Often, zoomed in printouts of the mapped locations were as valuable in locating sites as was the GPS unit. Substrate type at each site was verified. During each cast net survey, a total of 140 samples were collected, for a total of 420 samples.

The appropriate estimate of the mean number of suckers per cast net sample was calculated using the following formula:

$$\overline{y}_{st} = \left(\sum_{h=1}^{L} N_h \overline{y}\right) / N$$

where:

L = number of strata (8 here)

N = total number of units available for sampling (2595 here)

N_h = number of units in each stratum (h) available for sampling

n_h = number of units sampled in stratum h

y_{hi} = value obtained (number of fish) for the i^{th} unit in stratum h

and,

$\bar{y}_h$ = mean of the n_h values in stratum h = $(\sum_{i=1}^{n_h} y_{hi})/n_h)$

Density per square meter was calculated by dividing mean number per cast by 5 m^2 (the area sampled by the cast net). Shoreline abundance was then estimated by multiplying the resulting density by the total shoreline area. Total shoreline area was estimated by multiplying the linear shoreline distance by 10. We assumed 10 meters as the distance from the shore that shoreline substrates extend, but this number remains arbitrary. At a minimum, our population estimates can be considered an index of abundance. Confidence intervals for the population estimates were calculated using a bias-corrected bootstrap resampling procedure, adjusted for the fact that the true mean is not the median of the distribution of bootstrap estimates (Manly 1997).

Otter trawl

late summer/fall

Three otter trawl surveys were conducted in conjunction with each cast net survey on August 26-27, September 15-16, and October 6-7 to assess offshore abundance of age 0 suckers. A 5 m semi-balloon otter trawl with 16 mm bar mesh and a 6 mm bar mesh liner was used. Trawl directions and locations were randomly selected from a grid of coordinates at 1 km intervals covering Upper Klamath Lake. No site began within 1 km of the shore, and direction was changed in the field if the randomly selected direction was not possible. Each survey consisted of 15 tows, each tow was 20 minutes in duration, and exact distance of each tow was measured using differentially corrected GPS coordinates. This protocol was identical to 1995-1998. Offshore populations were estimated by multiplying the calculated offshore density (mean number per tow divided by area sampled) by the offshore area of Upper Klamath Lake.

Confidence intervals were estimated using a bootstrap resampling procedure similar to that of cast net confidence intervals. Whole lake population estimates were estimated by summing cast net and otter trawl estimates.

spring

Two otter trawl surveys were conducted April 7-8 and April 28-29 to assess the 1998 year class as age 1 fish. Sampling protocol was identical to late summer/fall sampling.

RESULTS and DISCUSSION

Spring otter trawl

No age 1 suckers were captured in either of the two spring otter trawl surveys in April 1999. Although spring otter trawl catches are usually low, the lack of suckers in spring 1999 probably reflects a downward trend in age 0 sucker abundance we have detected from the mid-1990s (Simon et al. 2000) (Figure 2).

Larval trawl

Sucker larvae in Upper Klamath Lake were abundant in 1999. Mean larval trawl catch rates in 1999 were higher than any year since larval sampling began in 1995, although they were similar to 1996 and 1997 (Figure 3). Larval trawl catch rates were substantially higher than those from 1998. Other indices also suggest larvae were abundant in 1999. The proportion of positive catches (catches >0) was 43% in 1999, higher than 1998 but lower than 1995 or 1996 (Table 2). The proportion of large catches (>100) was 5.0%, much higher than 1997 or 1998, slightly higher than 1995, but lower than 1996 (Table 2). Of the 6 larval surveys, catch rates were high in two (Figure 4). This is a departure from previous years when catch rates were never high (1998) or only high for one survey (1996, 1997). Although one larval survey was high in 1997, it did not persist as catches dropped by the next survey and catches with all gears remained low throughout the year. High levels of un-ionized ammonia that year may have inflicted high mortality on larvae (Simon et al. 1998). These data suggest larval abundance in 1999 was higher than in 1997 or 1998, and similar to 1995 and 1996. There was no correlation (r = -0.06) among adult spawning run indices (Markle et al. 2000) and larval indices from 1995-1999 (Figure 5).

Larvae were most abundant at sites U6 (Williamson River mouth) and U5 (Goose Bay) (Figure 6). Other sites of high abundance included U2 (Hagelstein Park), U10 (Stonehouse Ranch), U7 (Ball Bay), and U4 (Modoc Point). Similar to other years, catch rates of larval suckers in Agency Lake were considerably lower than in Upper Klamath Lake (Figures 3, 6, 7). Length frequencies of larval suckers are shown in Figure 8.

Beach seine

Age 0 suckers, as indexed by beach seine CPUE, were abundant in Upper Klamath Lake in 1999. Catch rates were lower than those from 1996 were, but higher or much higher than other years (Figure 9,10). The proportion of positive catches (>0) in 1999 was similar to 1995 and lower than 1996, but much higher than in 1997 and 1998 (Table 2). Similarly, the proportion of large catches (>25) was similar to 1995 and lower than 1996, but much higher than in 1997 and 1998 (Table 2). These data all suggest juvenile abundance in late June through August as measured by beach seine sampling was higher than 1997 and 1998, similar to 1995, but lower than 1996. Comparisons with beach seine catches from 1991-1994 are shown in Figure 9, but should be interpreted with caution, as data from these years were not collected as intensively or comparably as data from 1995-1999. There was little correlation (r = 0.22) among adult spawning run indices (Markle et al. 2000) and beach seine indices from 1995-1999 (Figure 11), but there was a much stronger correlation (r = 0.77) among larval trawl and beach seine indices (Figure 12).

Beach seine catches were highest at U6 (Williamson River mouth), U5 (Goose Bay), U2 (Hagelstein Park), and U10 (Stonehouse Ranch) (Figure 13).

Beach seine catches were low in Agency Lake. (Figures 9, 13, 14). Similar to most previous years, beach seine catches were primarily shortnose sucker. Of 3244 caught, 3059 (94.3%) were shortnose suckers, while 185 (5.7%) were Lost River suckers. Based on vertebral count distribution about 1% of the suckers identified as shortnose were probably Lost River suckers. A brief examination of a small subset of suckers caught in beach seines found no specimens with lip morphology resembling that of Klamath largescale sucker.

Length frequencies of suckers from beach seines (Figure 15) seem to reflect the bimodal distribution of larval suckers emigrating down the Williamson River in 1999 (Figure 16). Figure 16 clearly shows an early, smaller peak of emigrating larvae and a later, larger peak. These correspond well with June 29-30 and July 20-21 SNS length frequency data (Figure 15) that show a large peak of younger suckers and a smaller peak of older suckers. The addition of LRS to the length frequency histogram made little difference as the large number of SNS dominated the histogram.

Cast net

Cast net catches in 1999 were high; a total of 872 age 0 suckers were caught. In addition to our normal routine of identification, including vertebral and gill raker counts, each specimen was carefully examined in the laboratory for lip morphology. One specimen (0.1%) was identified as a Klamath largescale sucker. Of the remaining, 372 (43%) were Lost River suckers and 499 (57%) were shortnose suckers. Nearshore population estimates of age 0 Lost River sucker were 201,828 in the August survey, 65,556 in the September survey, and 59,945 in the October survey (Table 3). Nearshore estimates of age 0 shortnose sucker were 344,681 in August, 96,338 in September, and 61,533 in October (Table 3). Mean shoreline abundance for LRS was higher than 1995-1997, but similar to 1998, while mean shoreline abundance for SNS was higher than 1997 but similar to 1995-1996 and 1998 (Figure 17) (see caveat below for 1998 cast net data). Other indices suggest nearshore abundance was highest in 1999 compared to previous years. The proportion of positive catches (>0), and the proportion of large catches (>5 and >10) (Table 4) were all higher in 1999 than from 1995-1998.

Age 0 suckers were most common on gravel and small mixed particles (Table 5) in 1999, consistent with substrate use patterns from 1995-1998 (Simon et al. 2000). Catch-per-unit-effort on fine substrates was higher in 1999 (Table 5) than from 1995-1998 resulting from some catches in the southern end of the lake on fines. Consistent with distribution patterns from 1995-1998, most age 0 suckers in 1999 were found in the south end of Upper Klamath Lake (Figure 18), with scattered catches in Ball Bay, Wocus Bay, and the eastern shoreline, and little use of the northern margins of the lake. Length frequencies of LRS and SNS from cast net sampling are shown in Figure 19.

Otter trawl

Otter trawl catches in late summer/fall 1999 were the highest ever. The August 26-27 survey averaged 11.2 (9.41, LRS; 1.76, SNS) age 0 suckers per tow, well above the previous high for a survey of 1.27 in October 1995. The total number of age 0 suckers captured during this survey (168) exceeded the total of 60 age 0 suckers captured in all random trawl surveys from 1995-1998. Of these 60, 37 were caught in 1995 and only 23 from 1996-1998. Catches of both species dropped in the final two surveys (Figure 20), but the mean CPUE of all samples far exceeded the means from 1991-1998 (Figure 21). The mean of the estimated abundance of all 3 surveys for both species was higher in 1999 than any year from 1995-1998 (Figure 22). Population size was not estimated prior to 1995 since sampling was from fixed sites rather than random. Of 186 age 0 suckers caught otter trawling 156 (84%) were LRS and 30 (16%) were SNS. None were identified as KLS, although each specimen was examined carefully for lip morphology. Offshore population estimates were 470,970 for LRS and 88,659 for SNS during in the August survey, but declined in the last two surveys (Table 6). Length frequencies of trawl-caught suckers are shown in Figure 23. Catch distribution is shown in Figure 24.

Whole-lake population estimates

Mean whole-lake population estimate for age 0 Lost River sucker in 1999 was the highest since we began estimating population size in 1995 (Figure 25). The August estimate of 672,798 (Figure 26) far exceeded the estimate of 309,632 from August 1998. Nearly 70% of the August 1999 estimate was from offshore abundance. Lost River sucker estimates in the September surveys in 1999 were similar to 1995 and higher than 1996-1998, and were higher in October 1999 than any other year (Figure 26).

Mean whole-lake population estimate for age 0 shortnose sucker in 1999 was also the highest, but only slightly higher than 1995, 1996, and 1998 (Figure 25). The August estimate in 1999 for age 0 shortnose sucker was similar to 1996 and 1998, but higher than 1997, while September estimate was lower than 1995, but higher than 1996-1998, and October estimates were similar to 1996 and higher than 1995 and 1997-1998 (Figure 27).

These estimates, along with larval trawl and beach seine data, suggest that age 0 suckers in 1999 were substantially more abundant than in 1997 or 1998, and at least or more abundant than 1995-1996. We urge caution in interpreting the 1998 cast net data as these numbers are probably inflated from a single sample in which an inordinately large number (1168) of suckers were caught. Without this sample, cast net abundance data are similar to 1997. Our larval trawl and beach seine data from 1998 are also similar to that of 1997, and suggest that these two years probably represent poor recruitment. Our data suggests 1999 was a good year for sucker recruitment.

During the period 1995-1998, larval and juvenile sucker abundance generally declined (Simon et al. 2000). During this same period, adult spawning run indices of both LRS and SNS also declined (Markle et al. 2000). Adult spawning run indices continued to decline in 1999 (Markle et al. 2000), however, larval and juvenile numbers reversed their declining trends and were abundant in 1999, suggesting a poor stock-recruitment relationship.

As in all other years, age 0 LRS and SNS population estimates in September and October were less than August. September and October estimates averaged 87,000 LRS, down from nearly 700,000 in August , while September and October SNS estimates averaged 85,000, down from 433,000 in August. This consistent annual trend of sharply decreasing age 0 sucker numbers in late summer and fall remains a concern. We had been concerned that suckers might move offshore during September and October, where capture efficiency of the otter trawl might be poor, and thus we would underestimate abundance. High capture numbers in otter trawl sampling during August 1999 has reduced this concern and suggest offshore densities in previous years was in fact low, particularly in 1993 and 1996-1998. Of continuing concern is the loss of age 0 suckers through irrigation and power canals. Gutermuth et al. (2000) have shown large numbers of age 0 suckers being entrained out of Upper Klamath Lake during late summer of 1997 and 1998, the same time our abundance data sharply decreased. Preliminary data from 1999 suggest entrainment patterns were similar (B Gutermuth, pers. comm.).

Water quality

Dissolved oxygen (DO) and pH values measured for each fish collection activity are shown in Figure 28. Dissolved oxygen levels fluctuated between 7.12 and 11.65 mg/l and pH fluctuated between 7.42 and 9.10 during the first 4 sampling weeks. During the summer as *Aphanizomenon* blooms affected water quality, the range of DO and pH levels increased (Figure 28). During late June through October we collected 570 samples where DO was measured. Of these, 14 (2.5%) had DO less than 1.62 mg/l and these 14 samples caught 122 (2.1%) age 0 suckers. Saiki et al. (1999) reported 1.62 mg/l DO as the mean 96 hr LC_{50} value for juvenile Lost River sucker, and 1.34 mg/l for juvenile shortnose suckers. Ninety eight percent of our samples (555 of 570, late June-October) had DO>1.85 mg/l, the minimum level reported that resulted in low mortality in caged juvenile LRS in Upper Klamath Lake (Martin and Saiki 1999). On June 30 we measured DO to be 0.00 in Wocus Bay (site U9) and captured 67 age 0 suckers in 4 samples. The ranges of DO concentrations for all samples and those with age 0 suckers are shown in Figure 29. All our samples were collected during the daytime and missed nighttime minima in DO concentrations.

During late June through October, we measured pH at 570 samples. Of these, only 4 were pH>10.3, the mean 96 hr LC_{50} reported by Saiki et al. (1999) for juvenile Lost River sucker. These 4 samples caught 67 age 0 suckers, and were the same 4 samples where DO was 0.00 on June 30 in Wocus Bay. Saiki et al. (1999) reported mean 96 hr LC_{50} pH values of 10.39 for juvenile shortnose sucker. Meyer et al. (2000) reported pH of 10.0 as not causing significant mortality of juvenile Lost River suckers. The ranges of pH values for all samples and those with age 0 suckers are shown in Figure 29. These data suggest that elevated pH in 1999 was not a limiting water quality problem.

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Table 1. Particle size for each substrate group mapped in Upper Klamath Lake. Mixed substrates show percent of particle sizes in each group required to be classified in that group.

Substrate	Particle size (mm)
fines	< 0.06
sand	0.06 - 2
gravel	2 - 64
cobble	64 - 250
boulder	250 - 4000
smallmix	> 75% < 64
intermix	0.06 - 4000
largemix	> 75% > 64

Table 2. Proportion (%) of positive catches and proportion (%) of large catches from larval trawl and beach seine sampling, 1995-1999.

Year	Larval trawl		Beach seine	
	% > 0	% > 100	% > 0	% > 25
1995	51	3.4	52	20
1996	53	7.1	62	35
1997	44	1.7	34	10
1998	36	0.0	32	8
1999	43	5.0	55	23

Table 3. Nearshore population estimates of age 0 LRS and SNS from stratified random cast net sampling, 1999.

Species	Dates	95% LCL	Estimate	95% UCL
LRS	Aug 23-25	80,295	201,828	389,633
LRS	Sept 13-15	27,025	62,556	118,949
LRS	Oct 4-6	22,422	59,945	124,305
SNS	Aug 23-25	132,165	344,681	729,362
SNS	Sept 13-15	39,030	96,338	195,907
SNS	Oct 4-6	28,209	61,533	113,188

Table 4. Proportion (%) of positive catches and proportion (%) of large catches from stratified random cast net and random otter trawl sampling, 1995-1999.

Year	Cast net			Otter trawl		
	% > 0	% > 5	% > 10	% > 0	% > 5	% > 10
1995	11	2.1	1.7	53	0	0
1996	12	3.3	2.6	30	0	0
1997	5	1.0	0.5	2	0	0
1998	9	1.4	1.0	16	0	0
1999	22	6.4	3.6	53	18	11

Table 5. Mean CPUE (number per net) of age 0 Lost River and shortnose suckers captured during stratified random cast net sampling, August-October 1999.

	Species	
Substrate	LRS	SNS
fines	0.223	0.585
sand	0.038	0.154
gravel	1.622	1.822
cobble	0.887	0.468
boulders	0.000	0.067
smallmix	2.031	3.400
intermix	0.237	0.421
largemix	0.227	0.300

Table 6. Offshore population estimates of age 0 LRS and SNS from random otter trawl sampling, 1999.

Species	Dates	95% LCL	Estimate	95% UCL
LRS	Aug 26-27	160,480	470,970	916,858
LRS	Sept 15-16	0	3,344	10,245
LRS	Oct 6-7	16,571	48,541	92,964
SNS	Aug 26-27	17,825	88,658	185,990
SNS	Sept 15-16	0	5,989	14,954
SNS	Oct 6-7	0	7,220	18,303

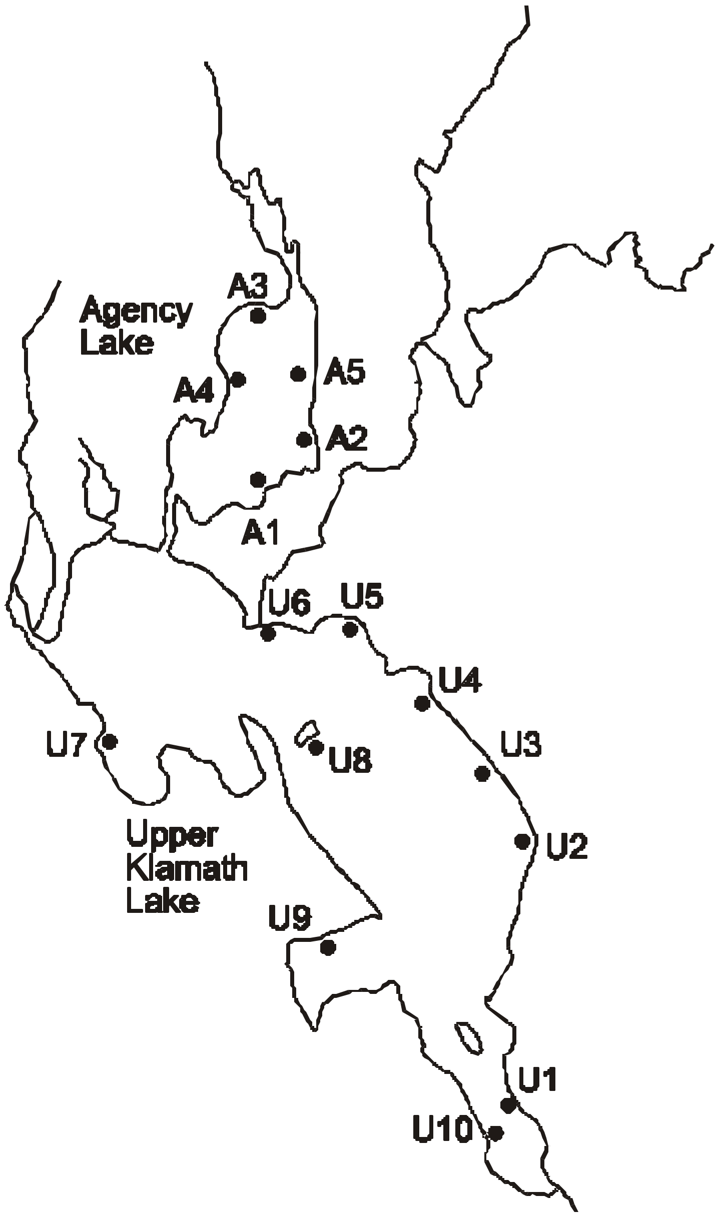


Figure 1. Larval trawl and beach seine sites in Upper Klamath and Agency lakes.

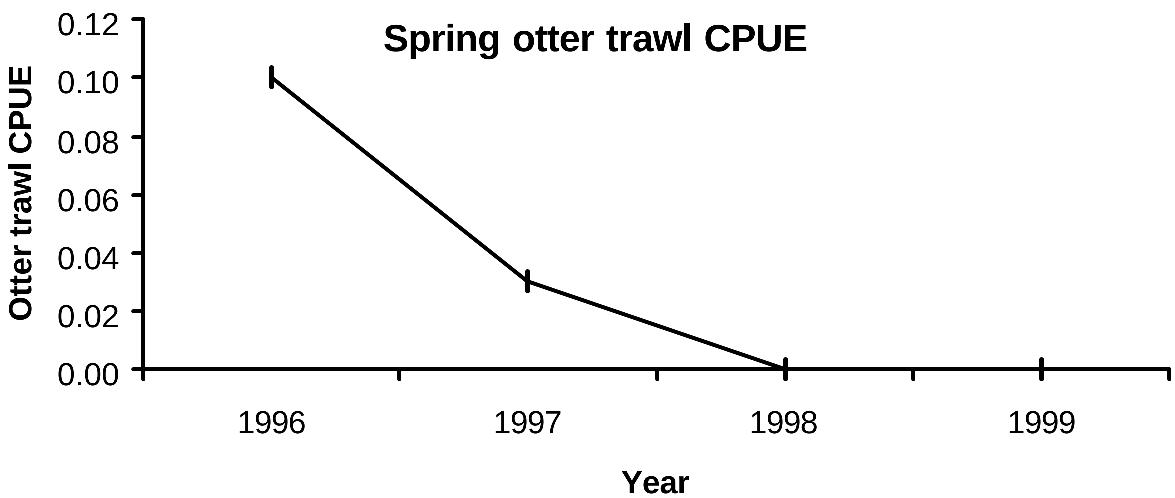


Figure 2. Spring otter trawl CPUE in Upper Klamath Lake, 1996-1999.

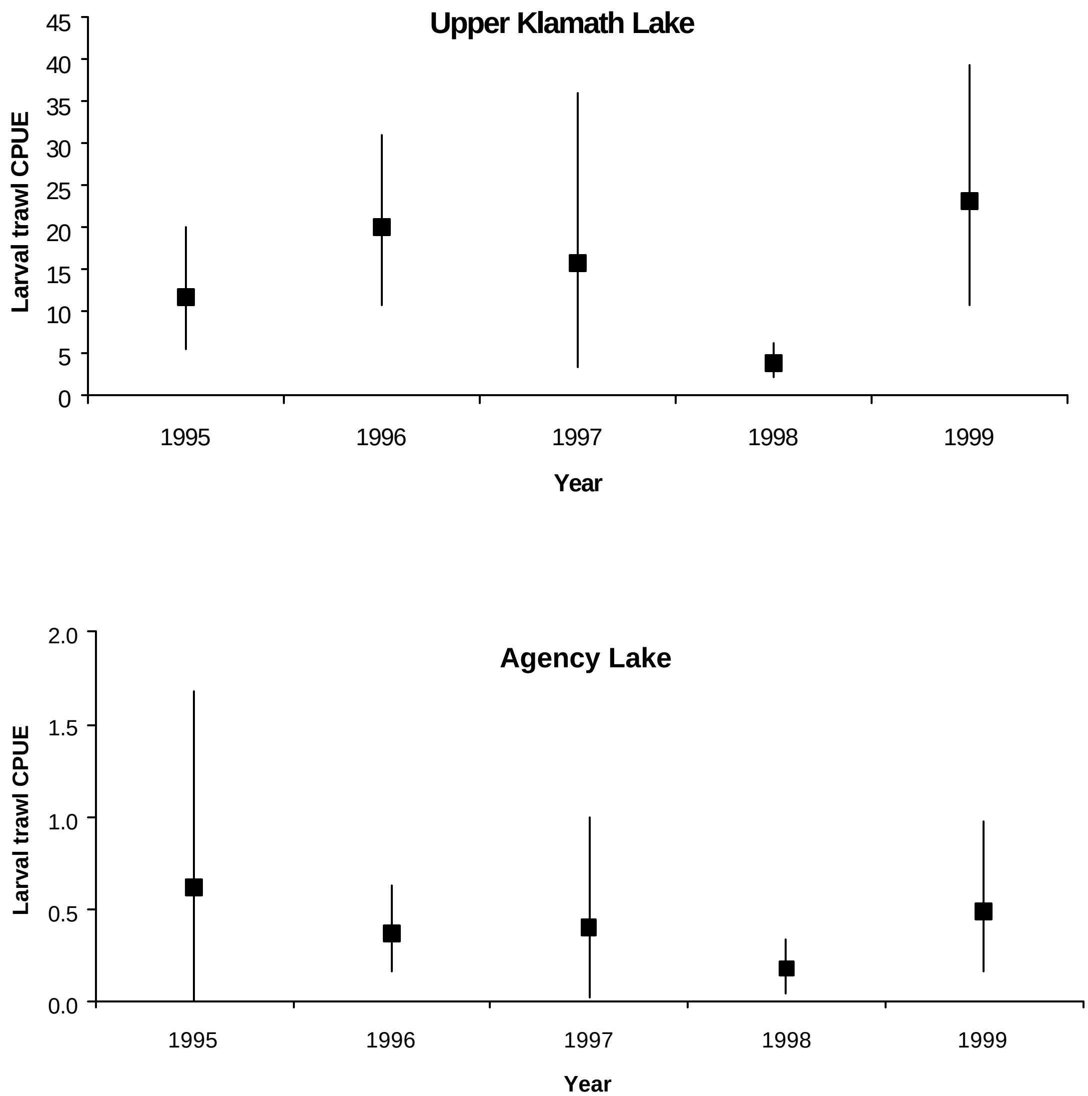


Figure 3. Larval trawl mean CPUE and 95% confidence intervals in Upper Klamath and Agency lakes, 1995-1999.

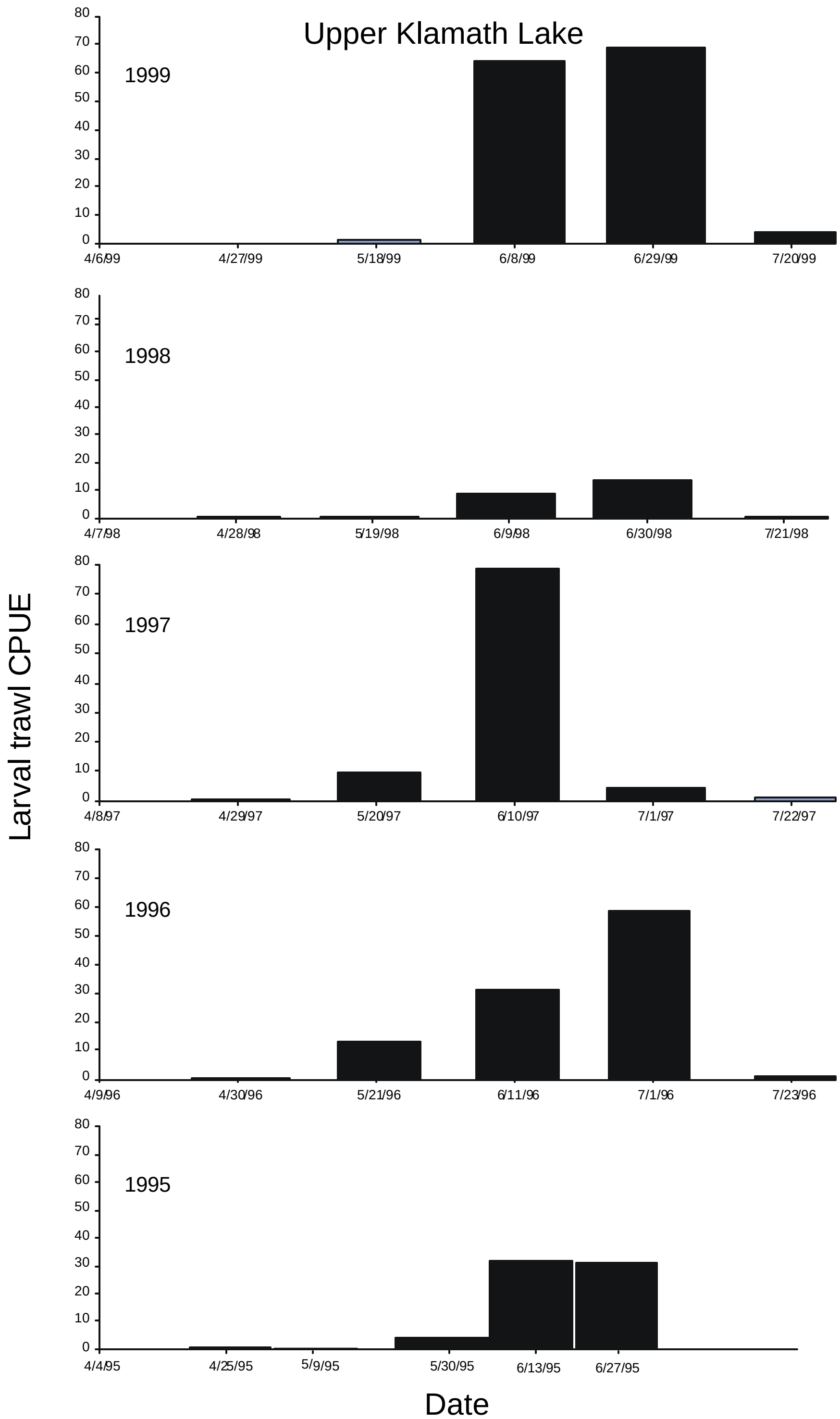


Figure 4. Larval trawl CPUE by sample series start date, 1995-1999, in Upper Klamath Lake.

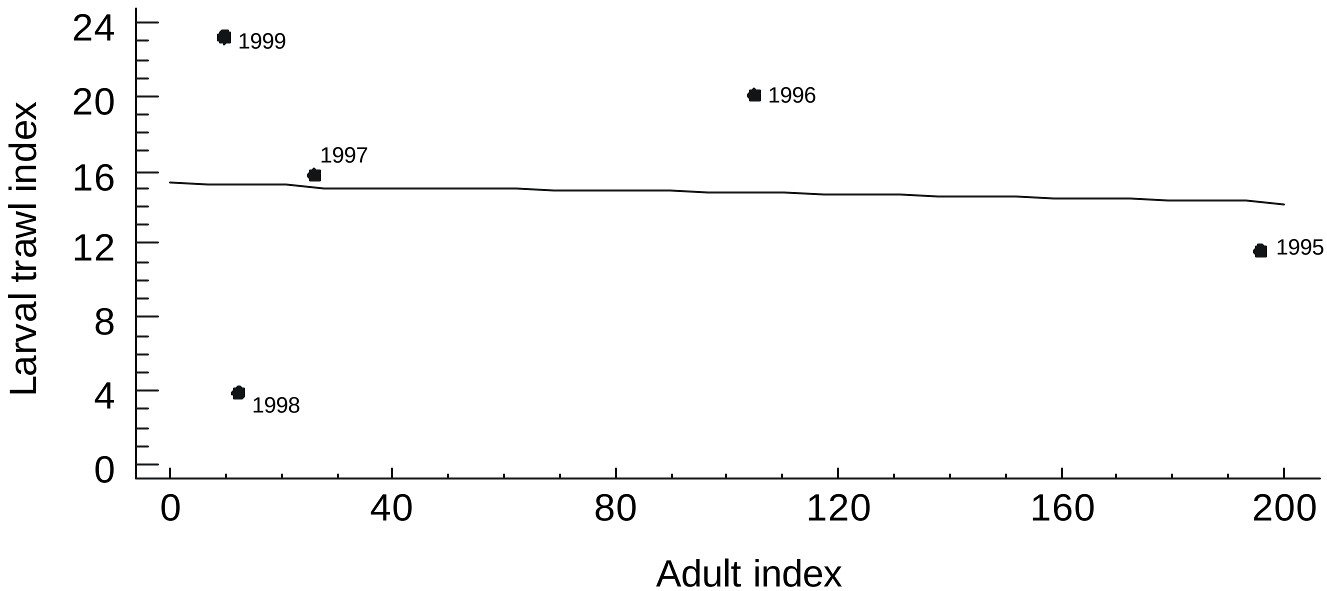


Figure 5. Relationship between adult spawning indices (LRS+SNS) and larval abundance indices, 1995-1999. Adult indices from Markle et al. (2000). *r* = -0.06

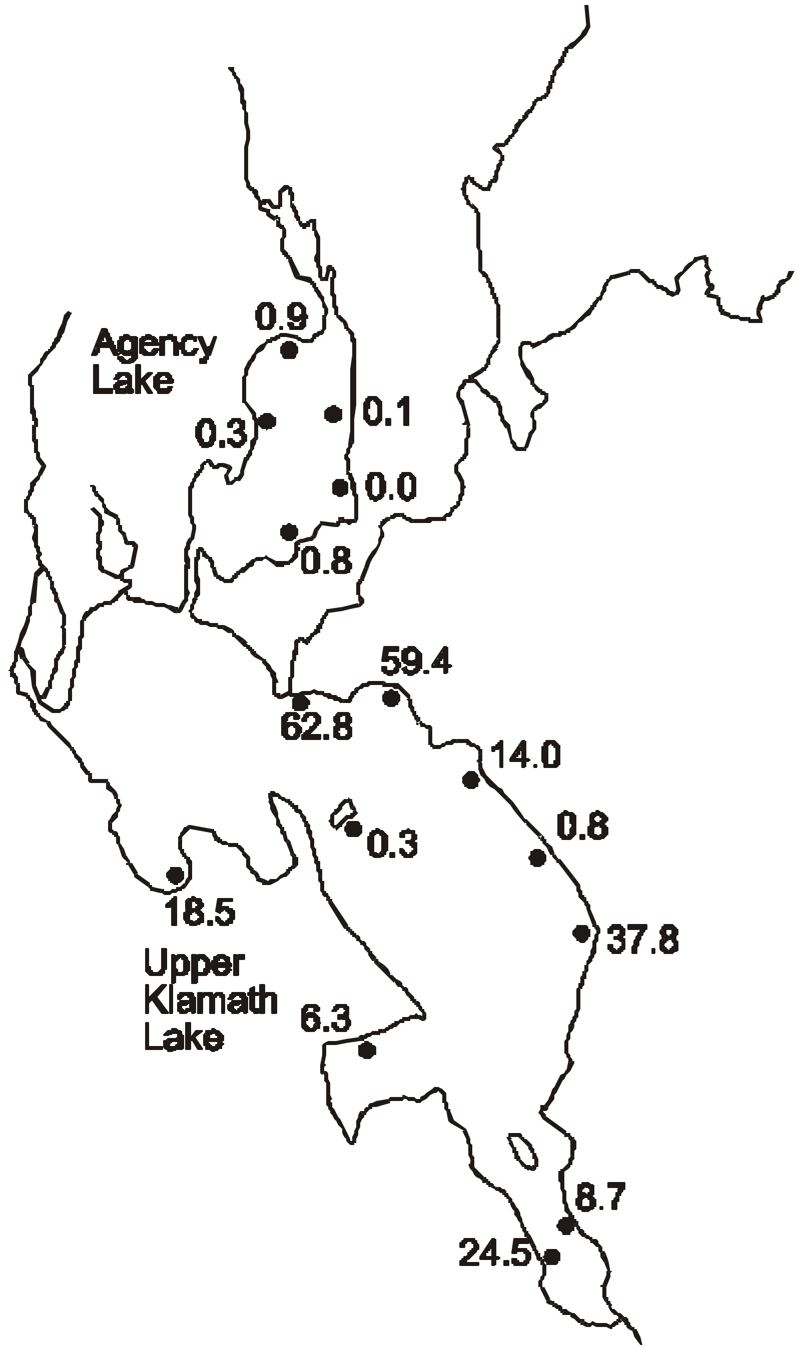


Figure 6. Larval trawl CPUE by site in Upper Klamath and Agency lakes, 1999.

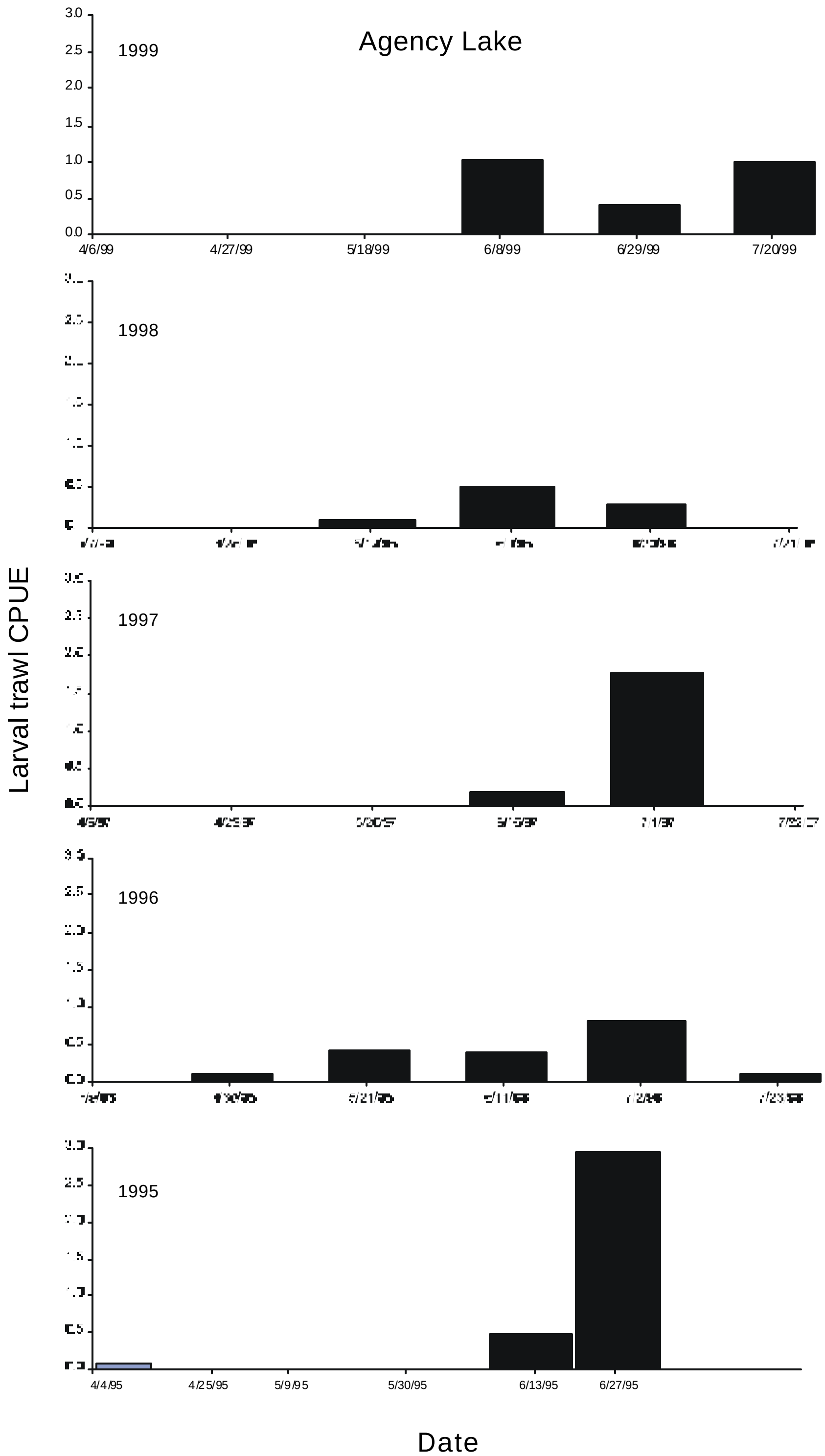


Figure 7. Larval trawl CPUE by sample series start date, 1995-1999, in Agency Lake.

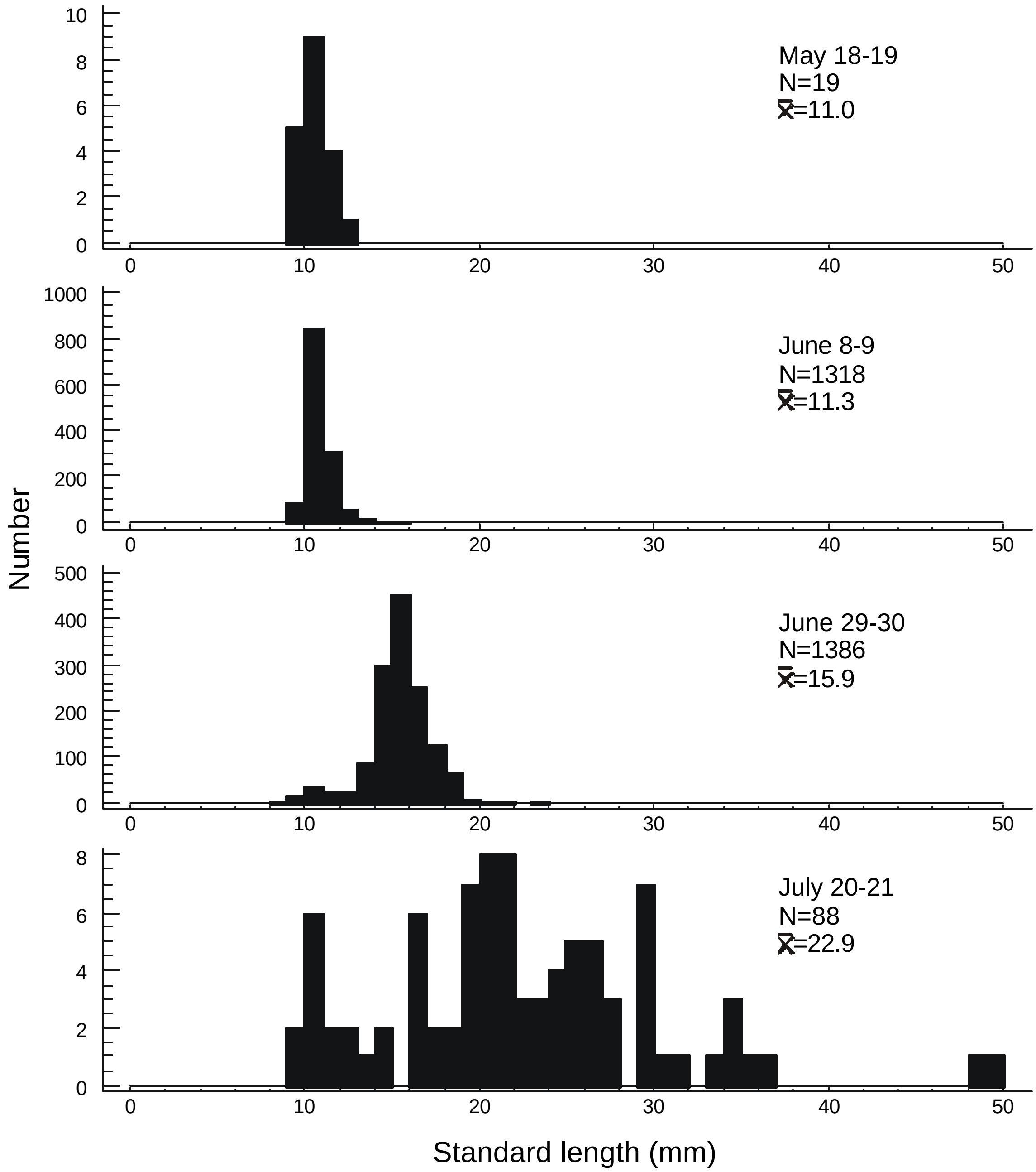
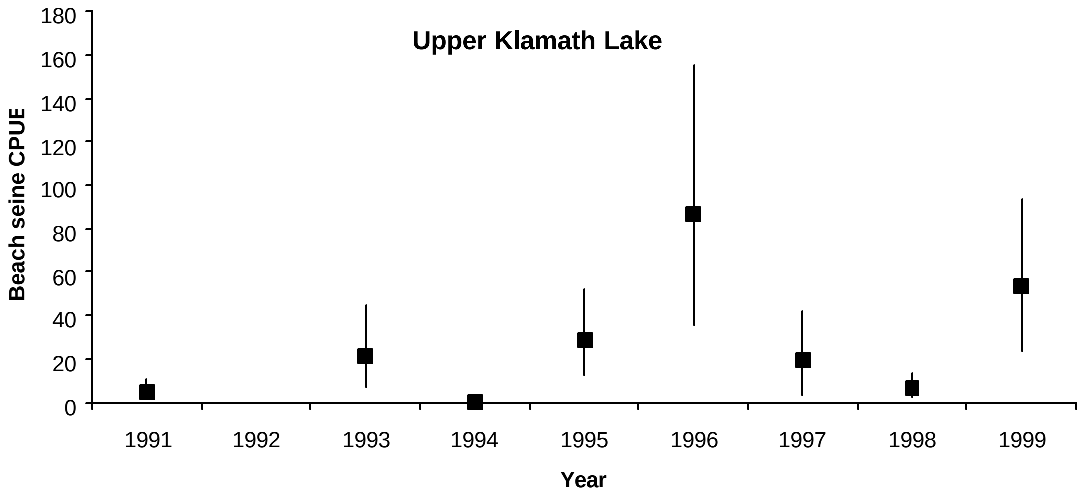


Figure 8. Length frequency of age 0 suckers from Upper Klamath Lake during fixed site larval trawl sampling, 1999. Measurements taken from radiographs of ethanol-preserved specimens unadjusted for shrinkage.



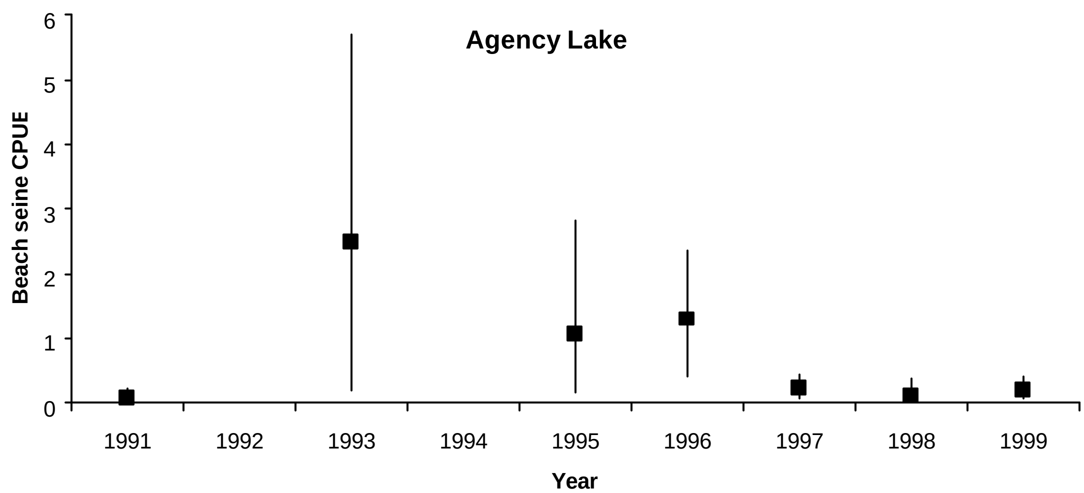


Figure 9. Beach seine mean CPUE and 95% confidence intervals in Upper Klamath and Agency lakes, 1995-1999. Data restricted to late June – August.

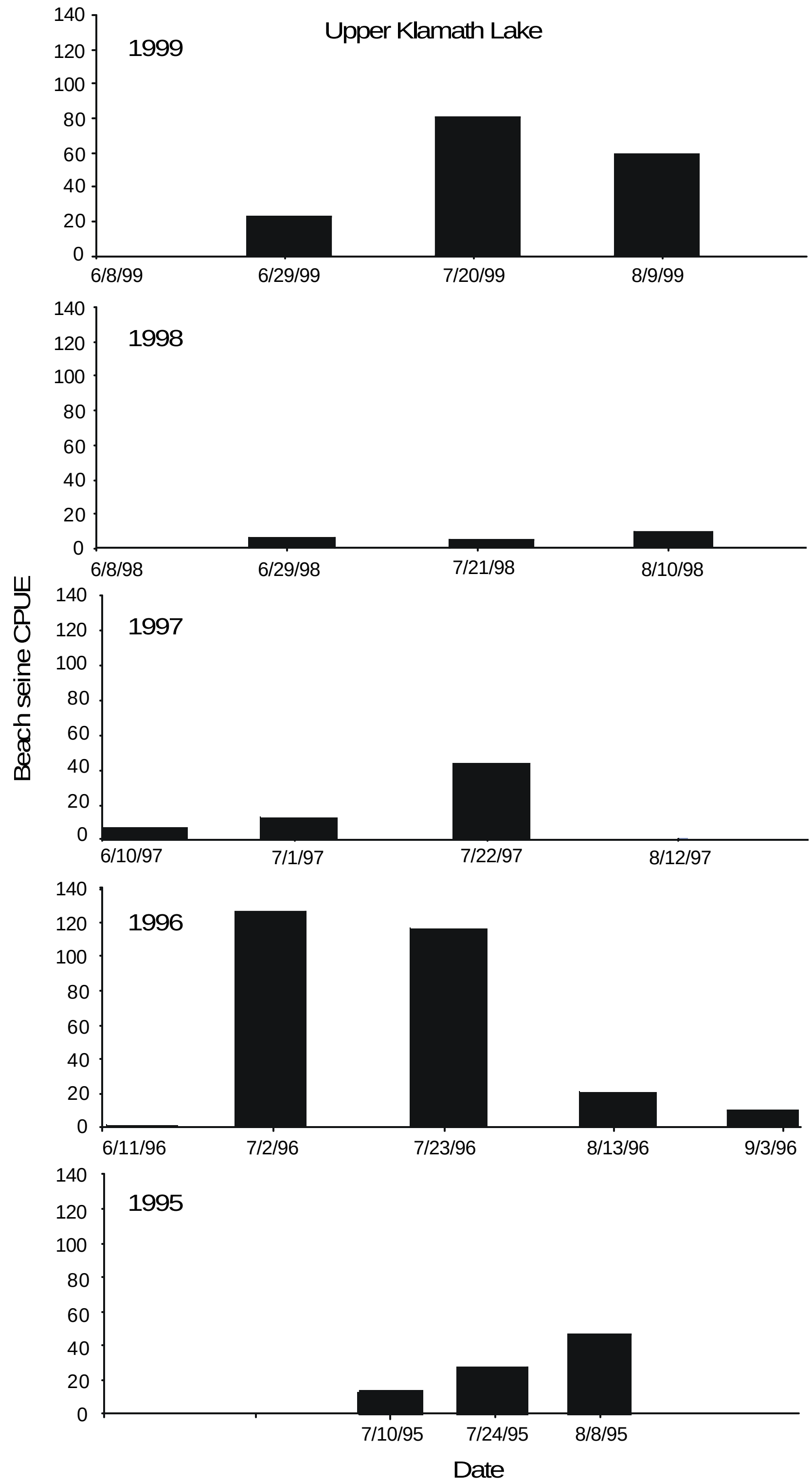


Figure 10. Beach seine CPUE by sample series start date, 1995-1999, in Upper Klamath Lake.

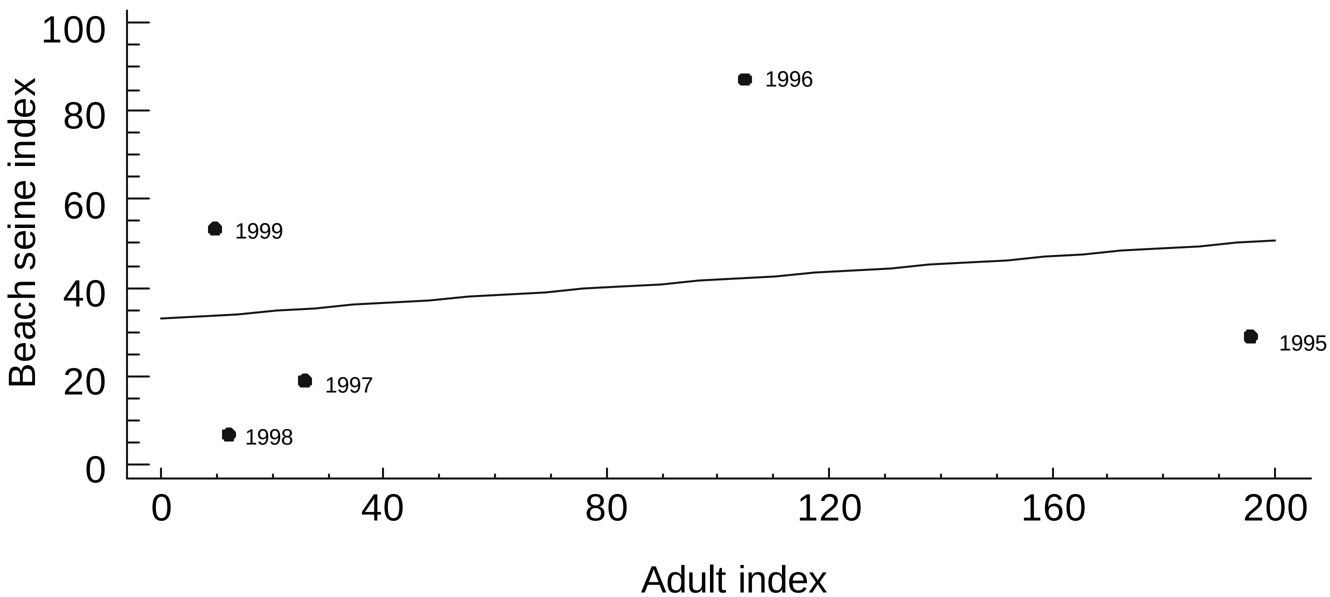


Figure 11. Relationship between adult spawning indices and beach seine abundance indices, 1995-1999. Adult indices from Markle et al. (2000). r = 0.22

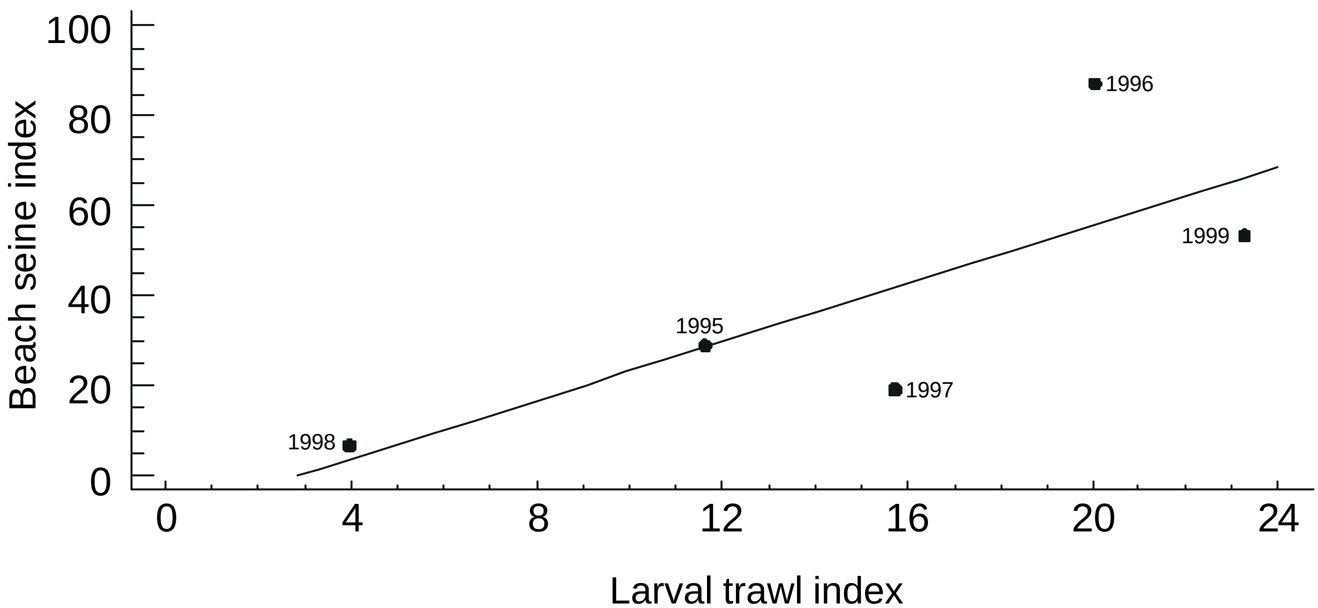


Figure 12. Relationship between larval trawl indices and beach seine abundance indices, 1995-1999. $r = 0.77$

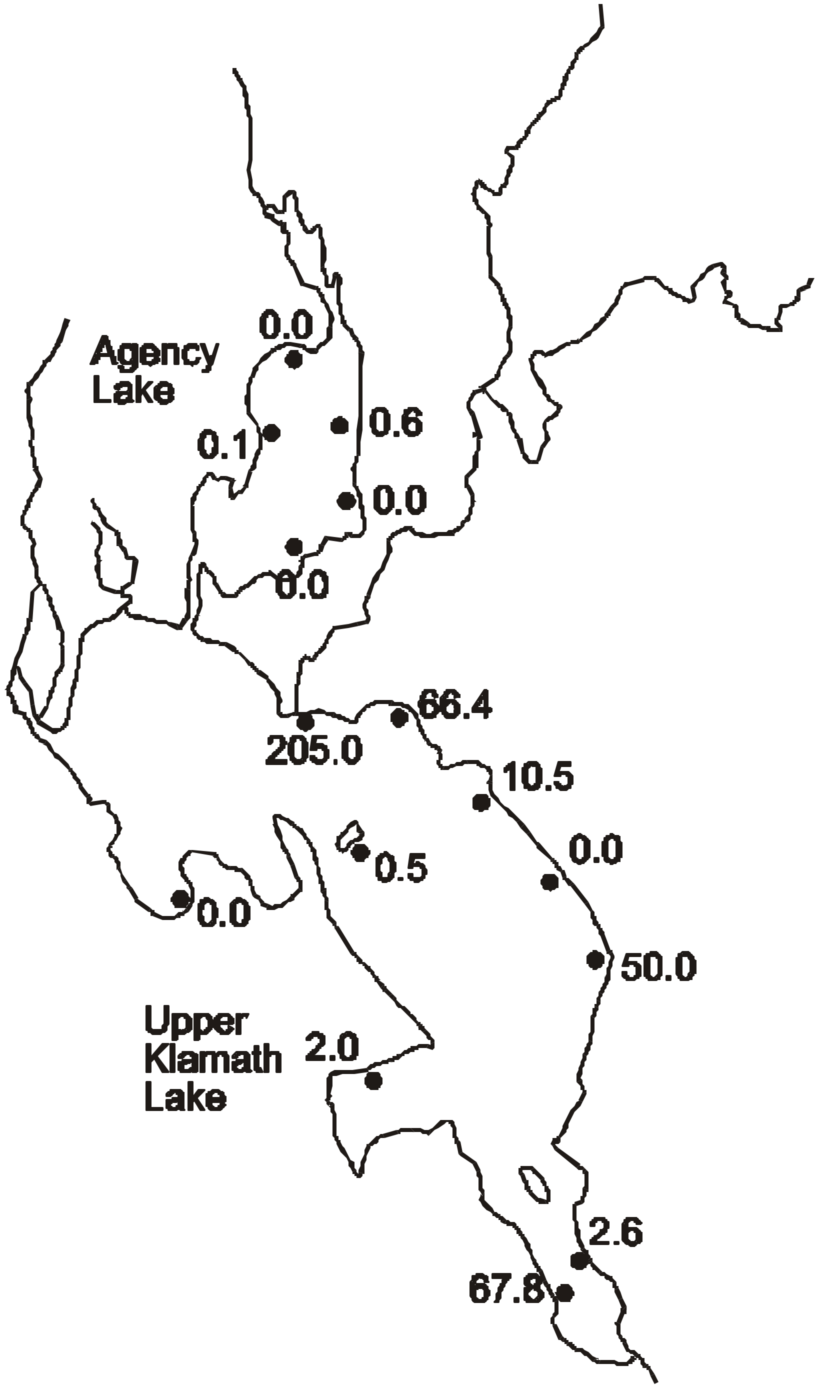


Figure 13. Beach seine CPUE by site in Upper Klamath and Agency lakes, 1999.

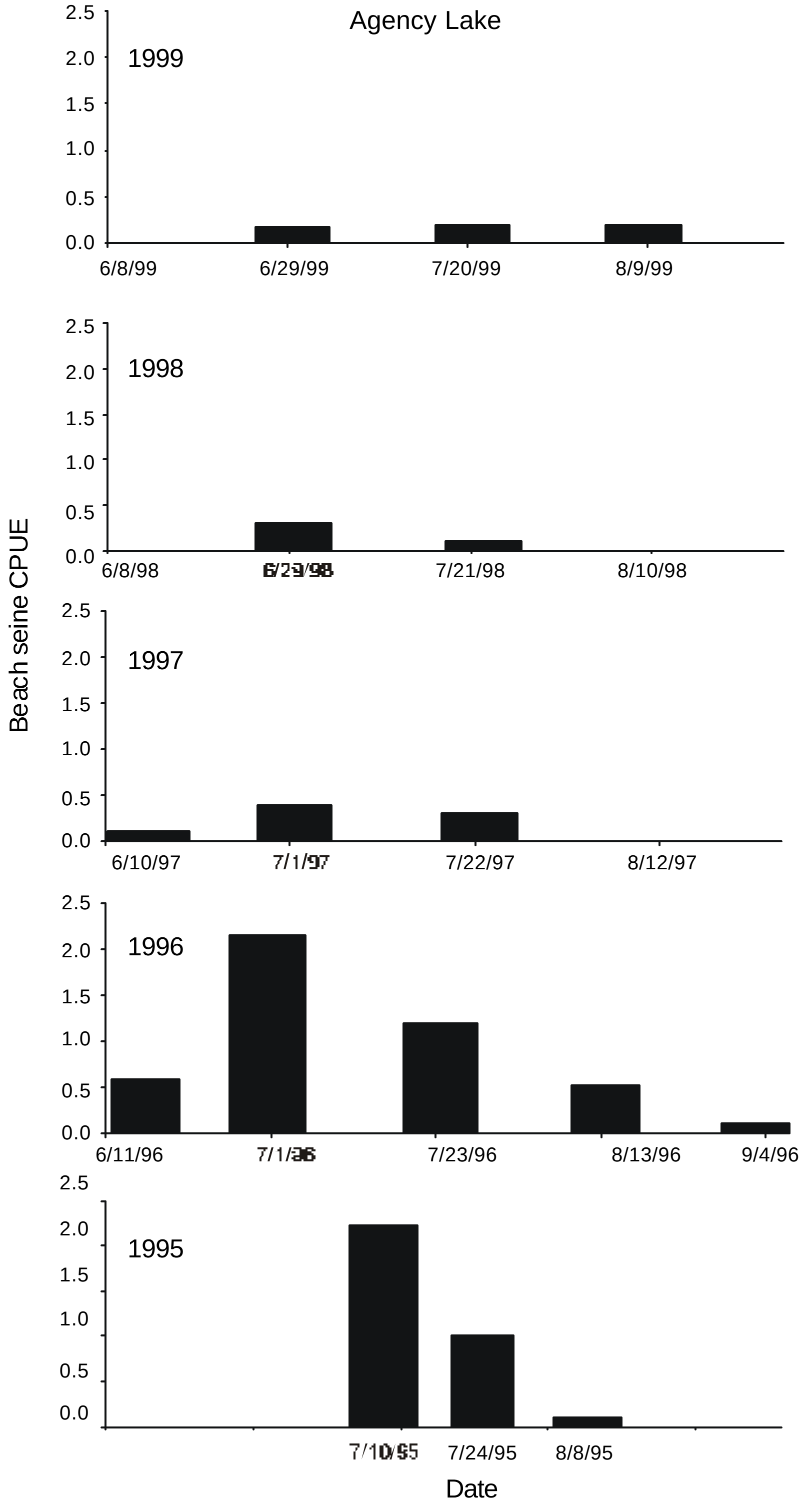


Figure 14. Beach seine CPUE by sample series start date, 1995-1999, in Agency Lake.

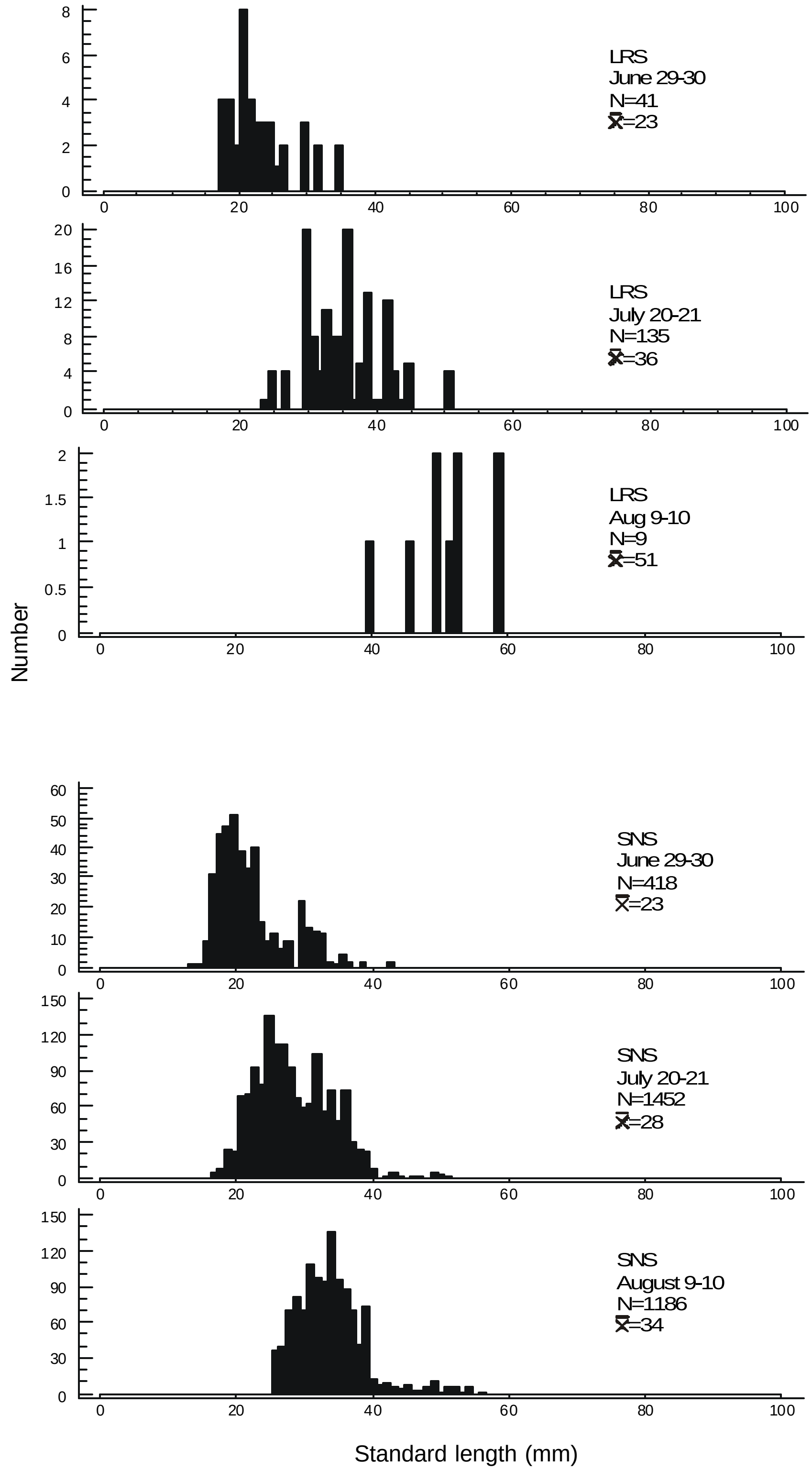


Figure 15. Length frequency of age 0 Lost River and shortnose suckers from Upper Klamath and Agency lakes during fixed site beach seine sampling, 1999. Measurements taken from radiographs of ethanol-preserved specimens unadjusted for shrinkage.

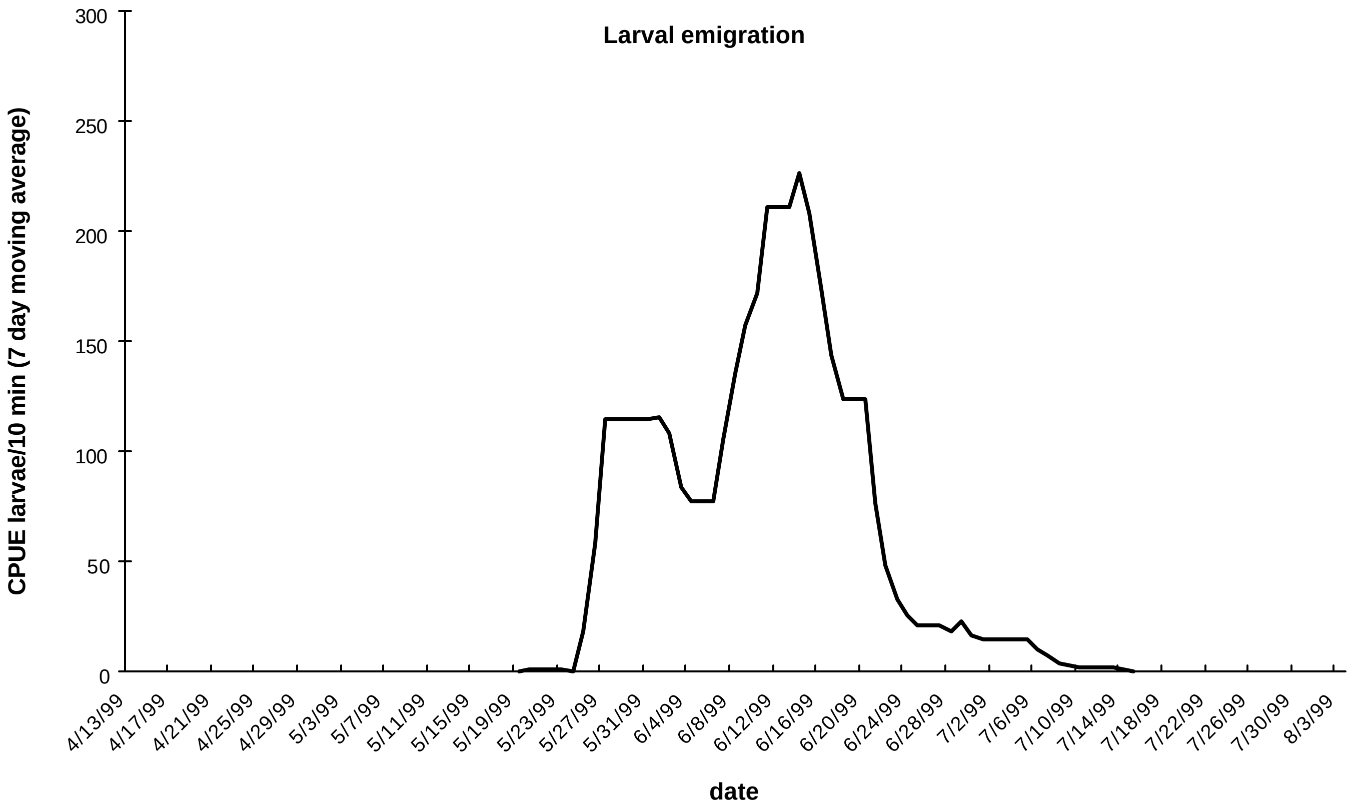


Figure 16. Pattern of larval sucker emigration down the Williamson River, 1999. Figure from Markle et al. (2000).

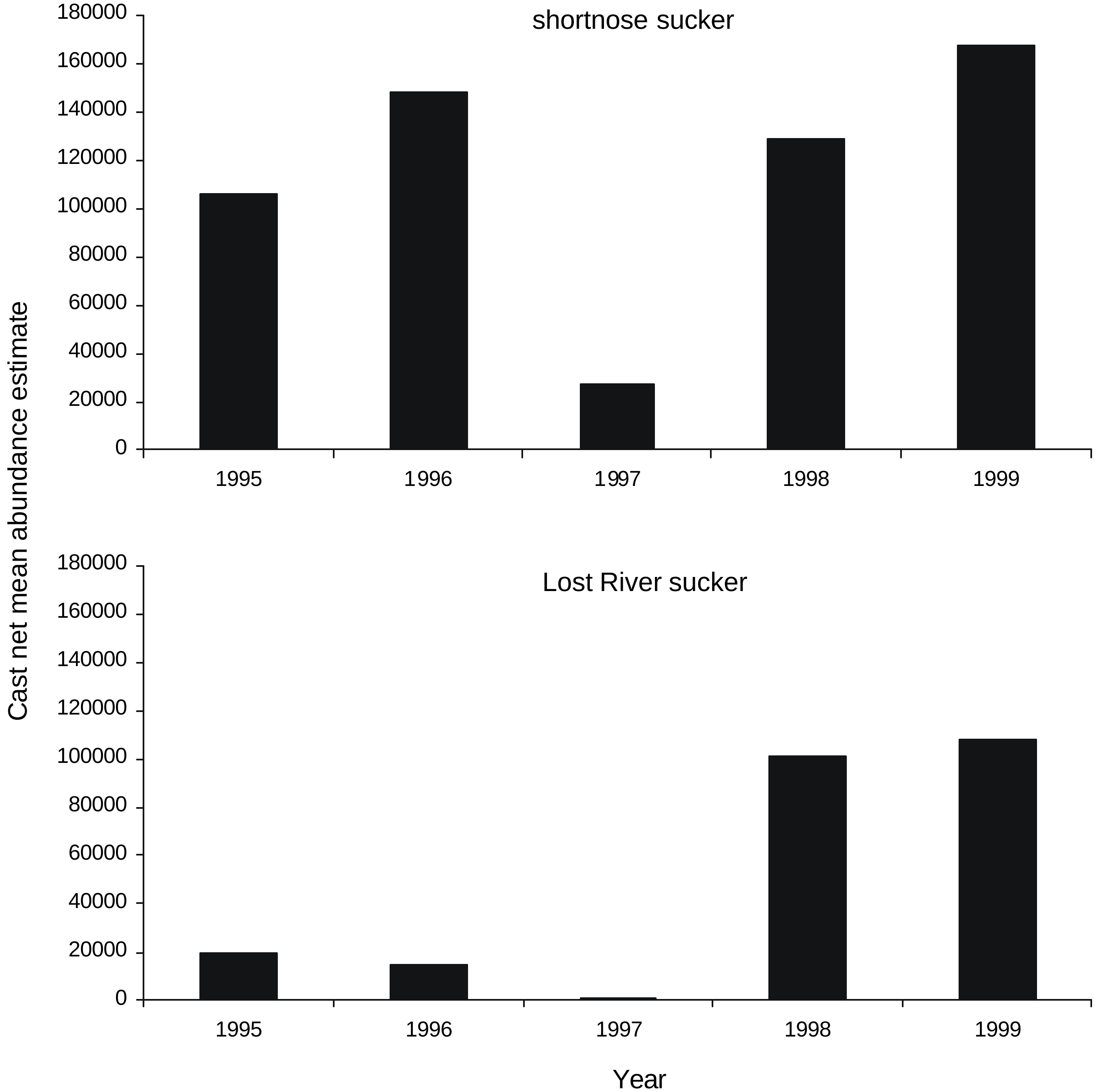


Figure 17. Mean shoreline cast net population estimates, 1995-1999. These represent the arithmetic mean of all three surveys 1996-1999, and the arithmetic mean of the two surveys in 1995.

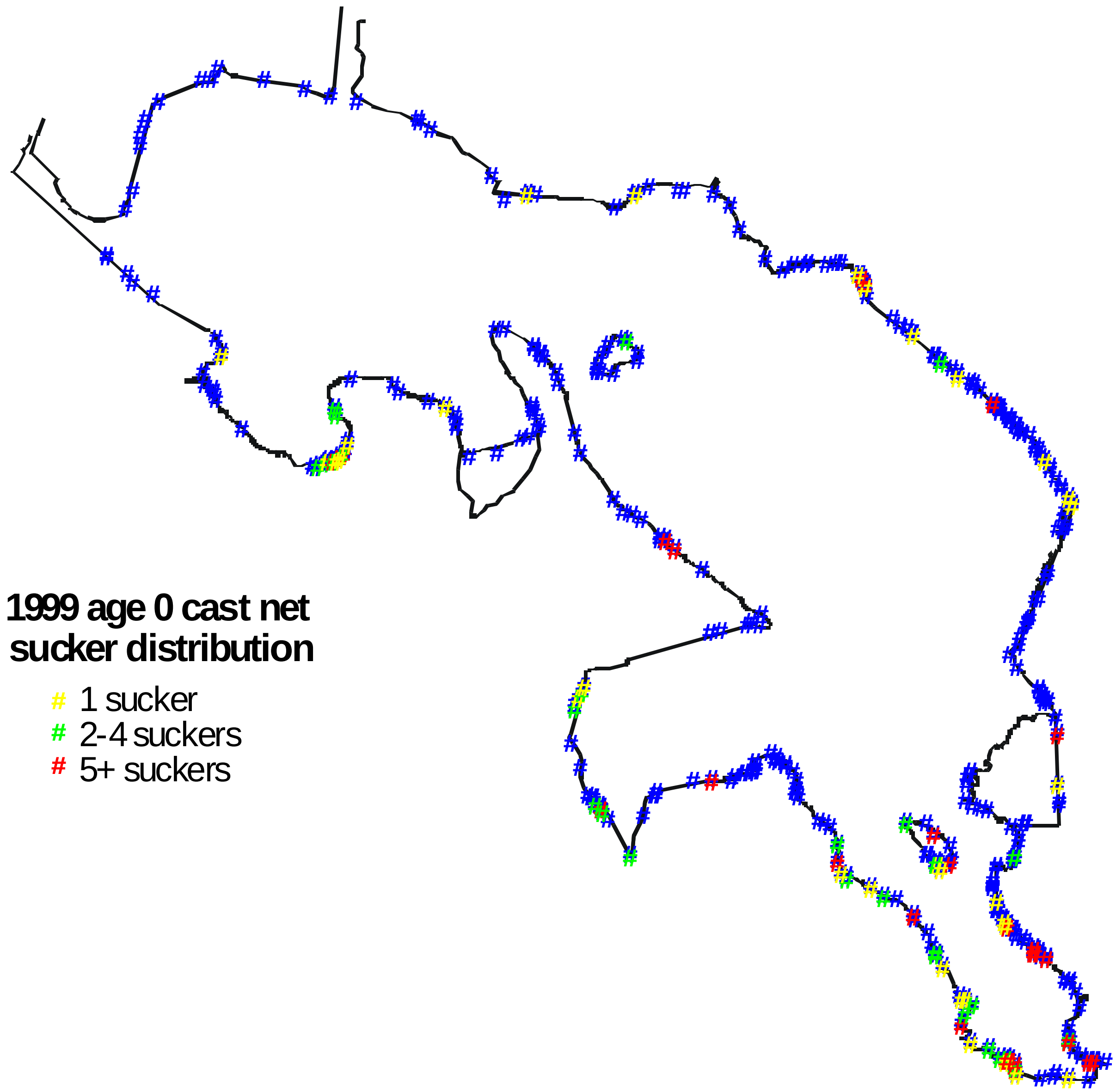


Figure 18. Distribution of age 0 suckers in Upper Klamath Lake from late summer/fall stratified random cast net sampling, 1999. Blue dots are samples with zero suckers.

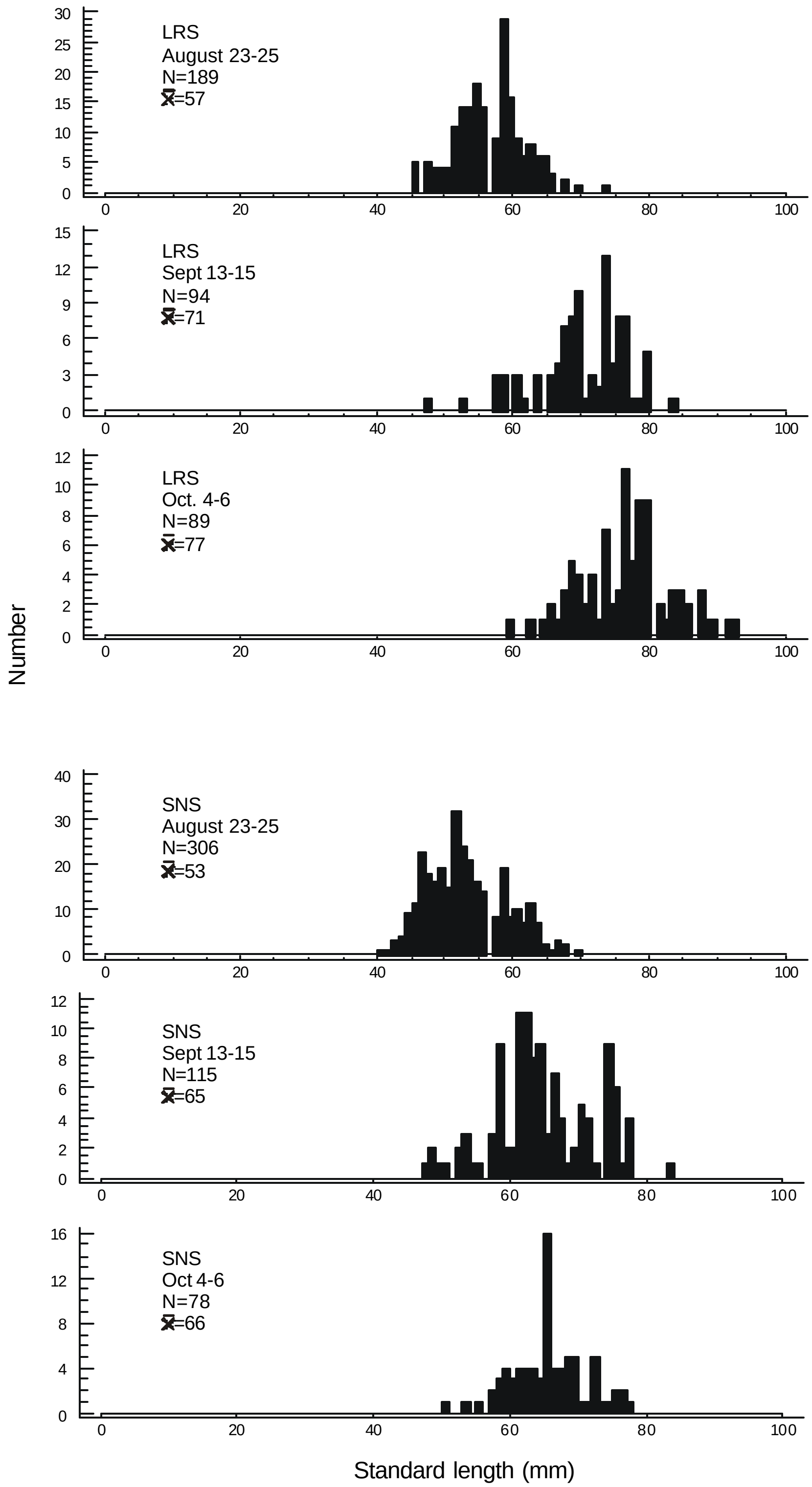
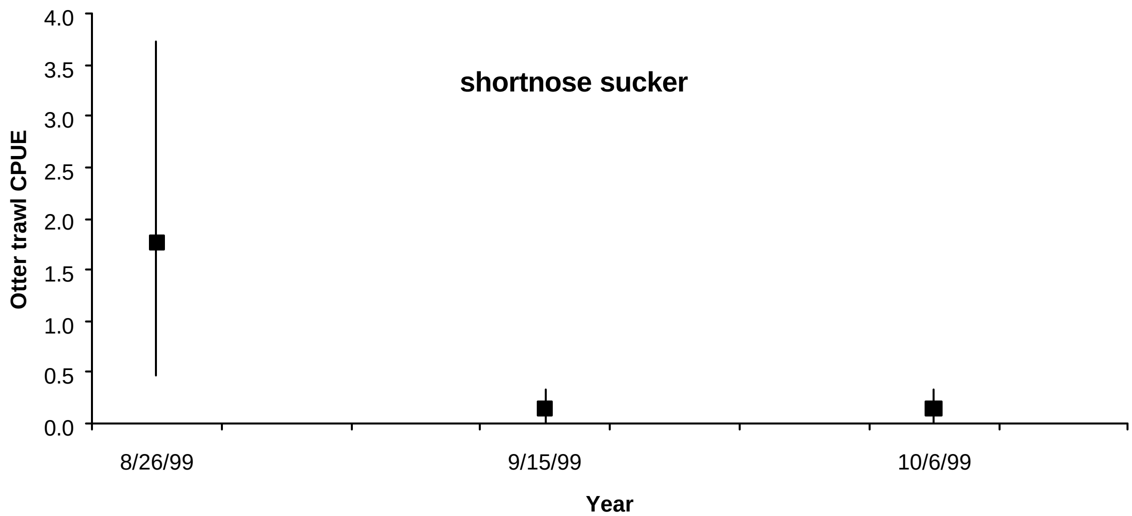


Figure 19. Length frequency of age 0 Lost River and shortnose suckers from Upper Klamath Lake during stratified random cast net sampling, 1999. Measurements taken from radiographs of ethanol-preserved specimens unadjusted for shrinkage.



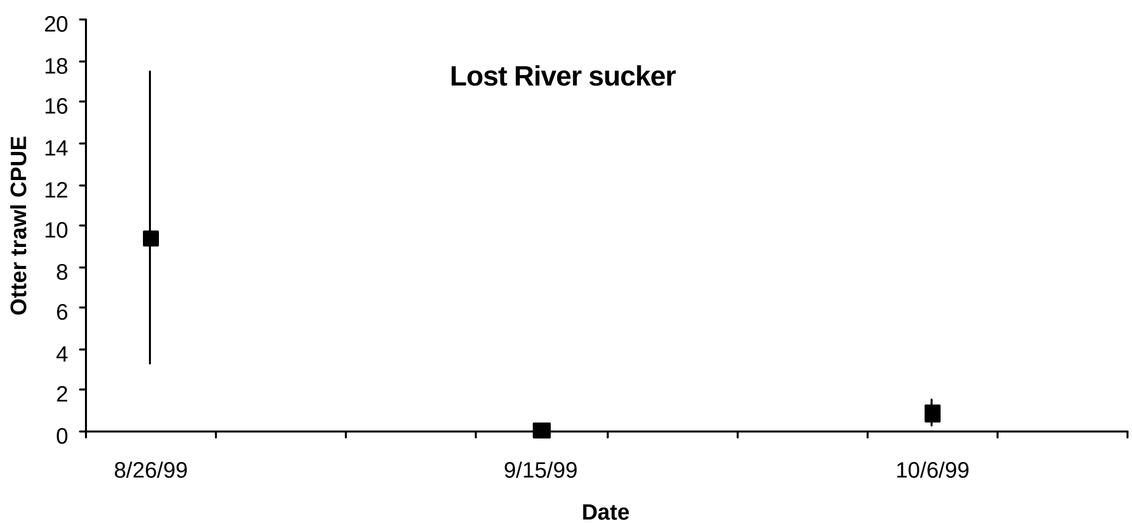
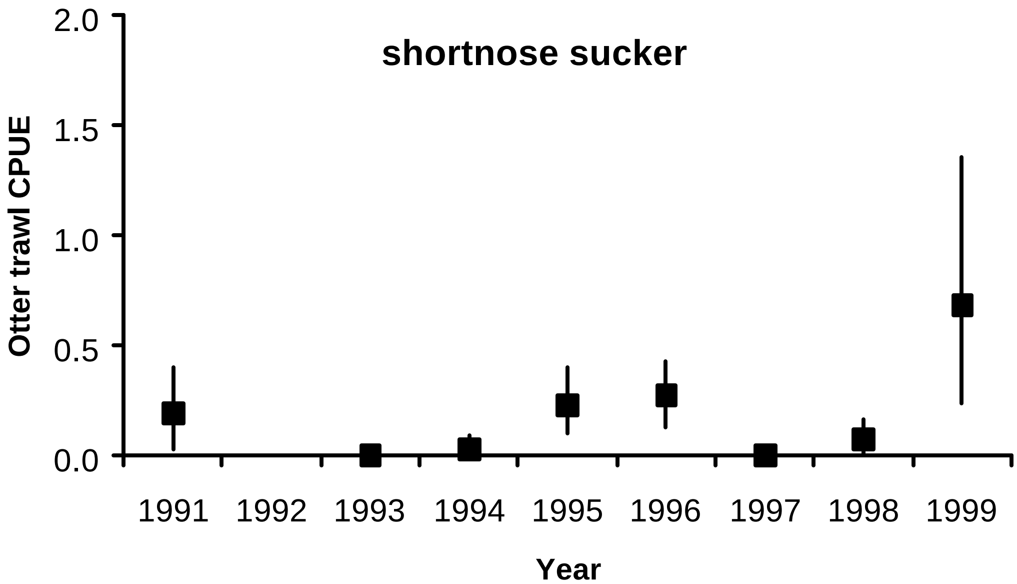


Figure 20. Late summer/fall otter trawl CPUE and 95% confidence intervals in Upper Klamath Lake by survey start date.



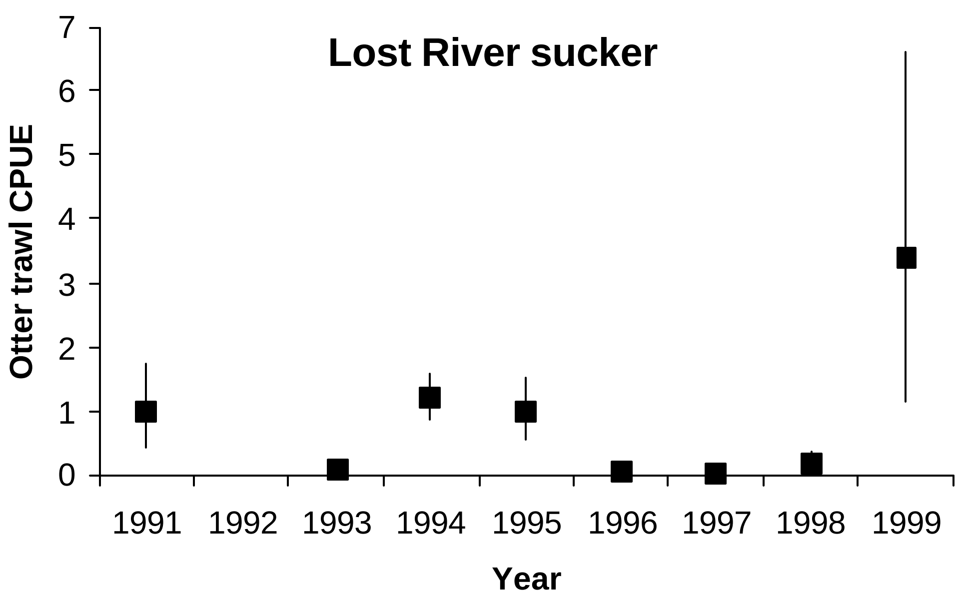


Figure 21. Late summer/fall otter trawl mean CPUE and 95% confidence intervals in Upper Klamath Lake, 1991-1999.

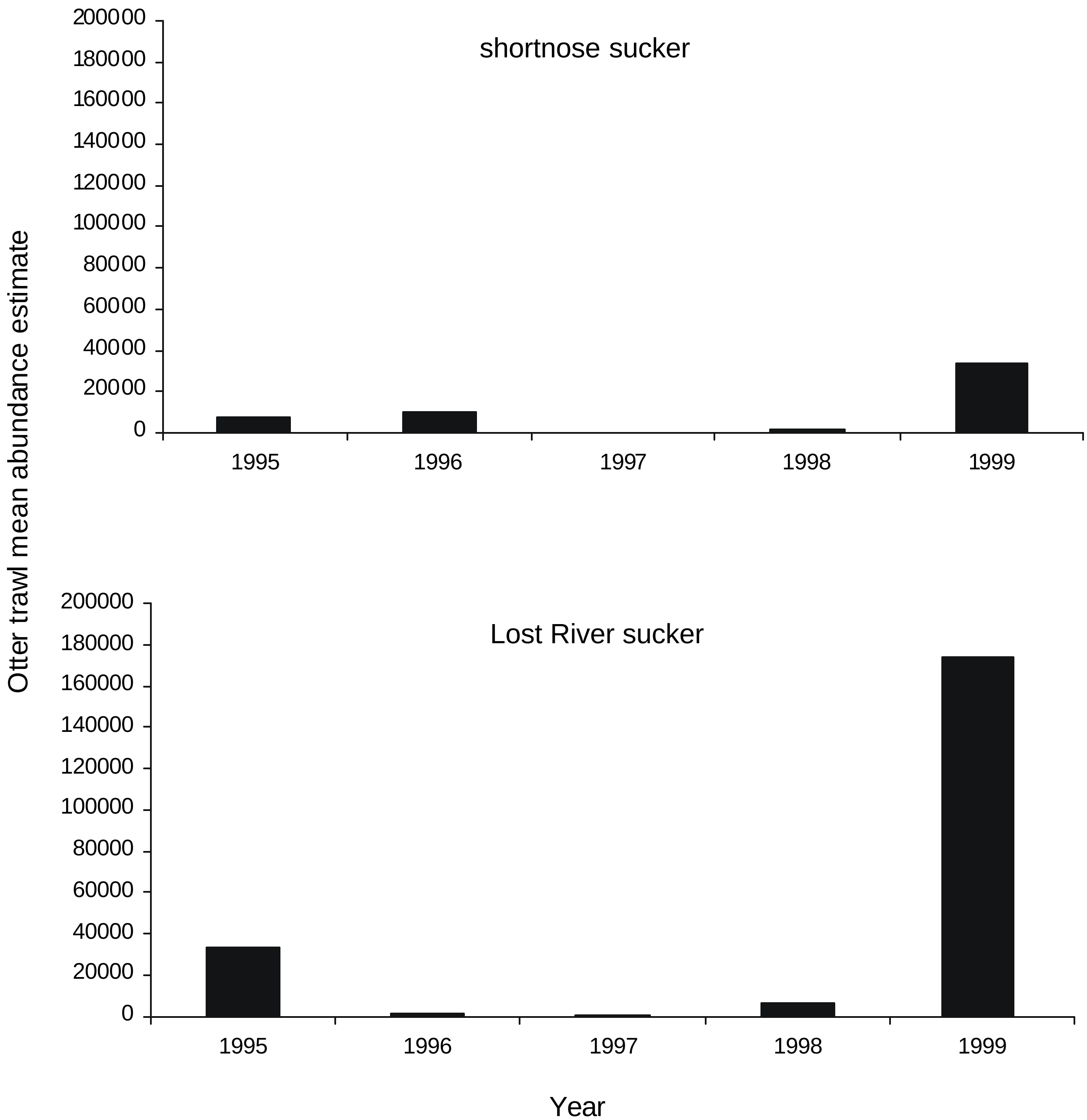


Figure 22. Mean offshore otter trawl population estimates, 1995-1999. These represent the arithmetic mean of two surveys 1995-1996, and the arithmetic mean of three surveys in 1997-1999.

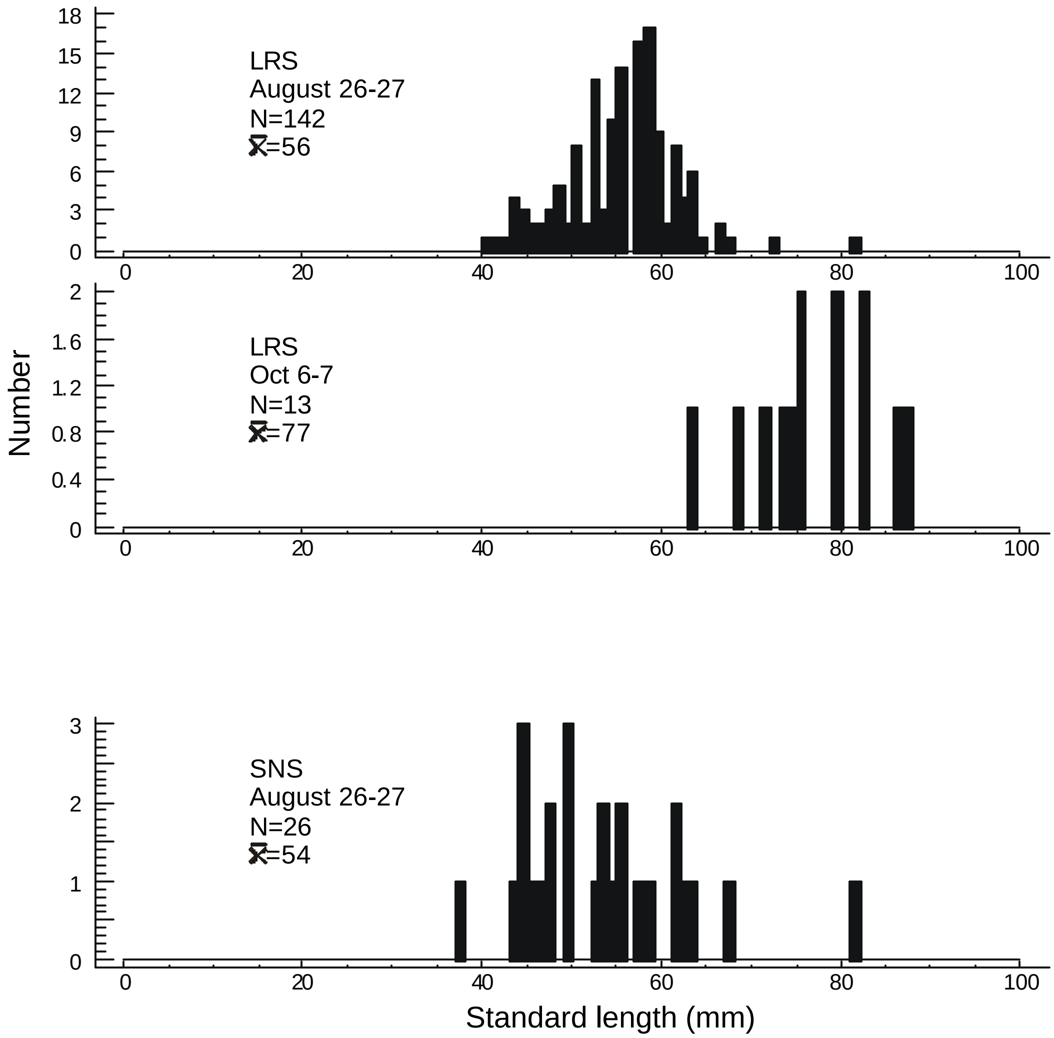


Figure 23. Length frequency of age 0 Lost River and shortnose suckers from Upper Klamath Lake during random otter trawl sampling, 1999. Measurements taken from radiographs of ethanol-preserved specimens unadjusted for shrinkage.

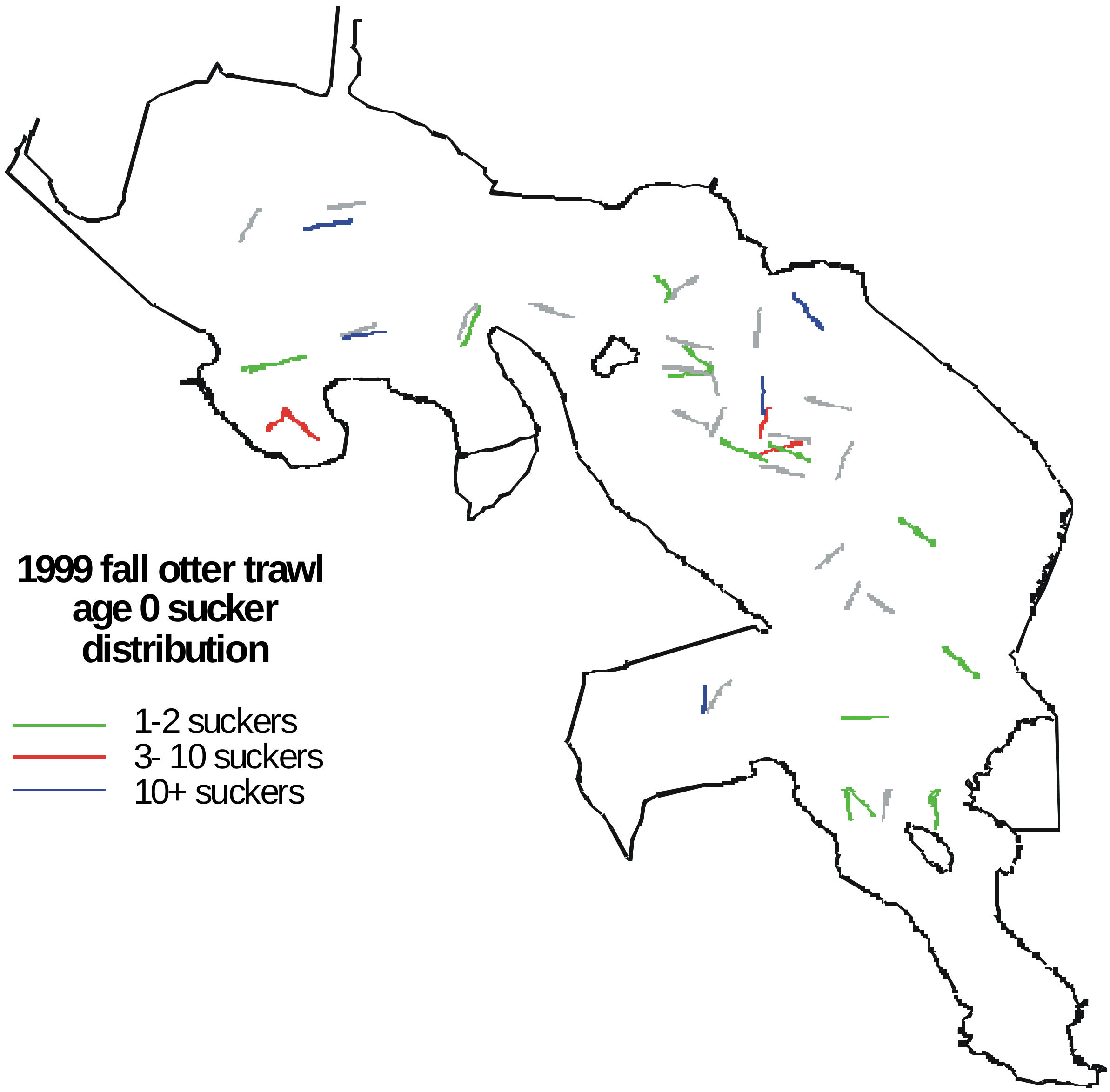


Figure 24. Distribution of age 0 suckers in Upper Klamath Lake from late summer/fall random otter trawl sampling, 1999. Gray lines are samples with zero suckers.

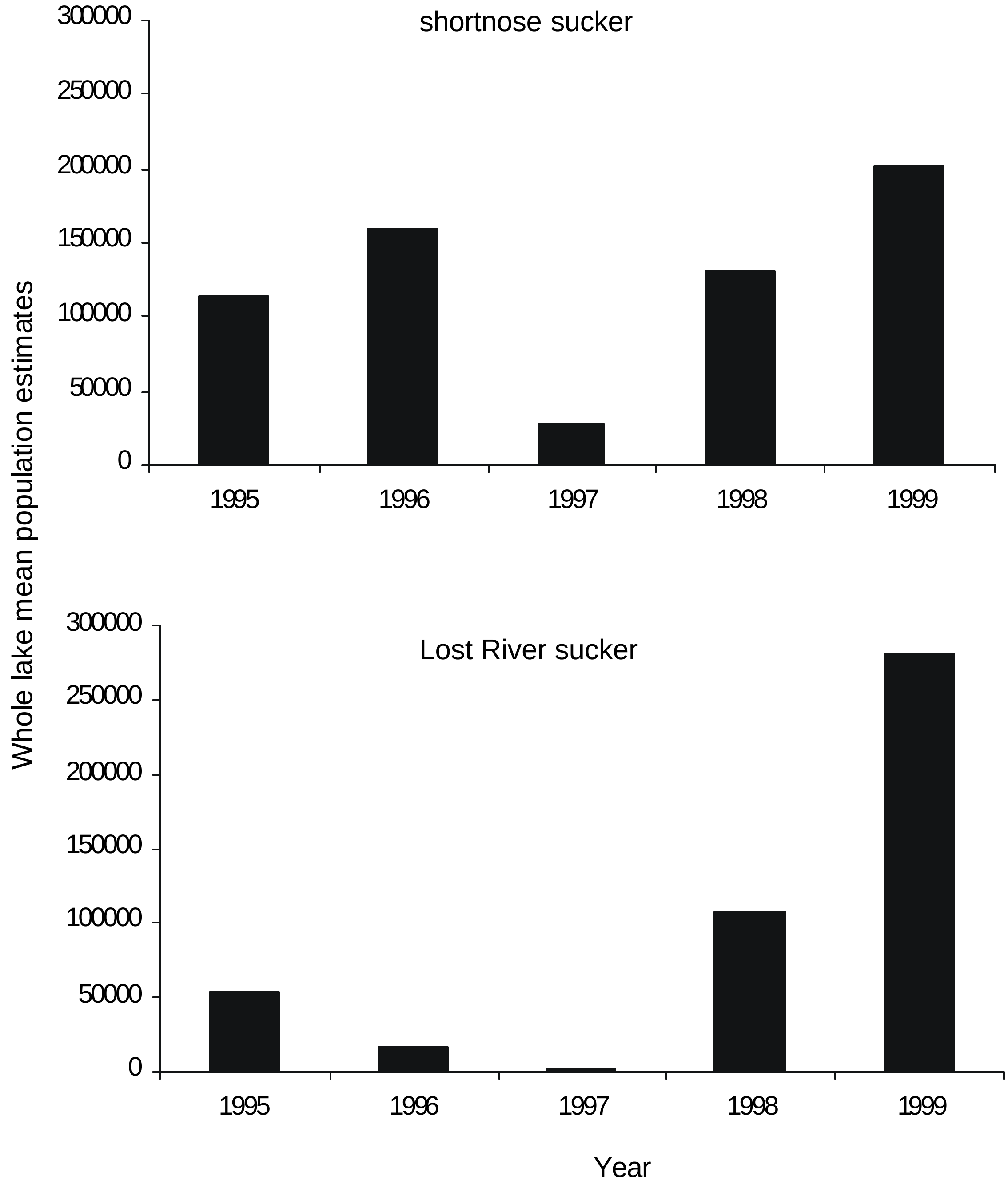


Figure 25. Mean population (offshore+nearshore) estimates, 1995-1999. These represent the sum of the arithmetic mean of cast net and otter trawl surveys.

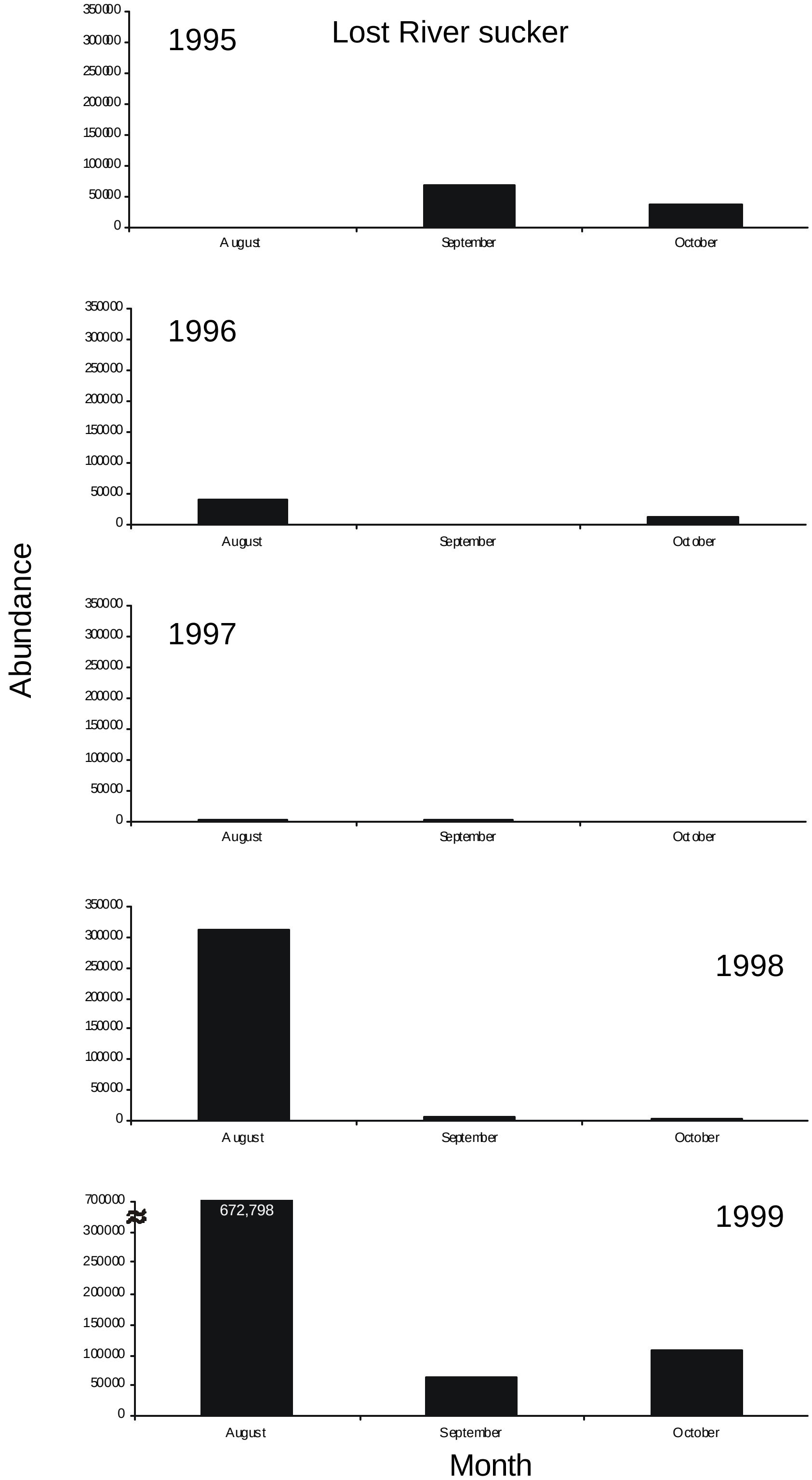


Figure 26. Lakewide population estimates of age 0 Lost River sucker in Upper Klamath Lake by month, 1995-1999. There was no sampling in August 1995.

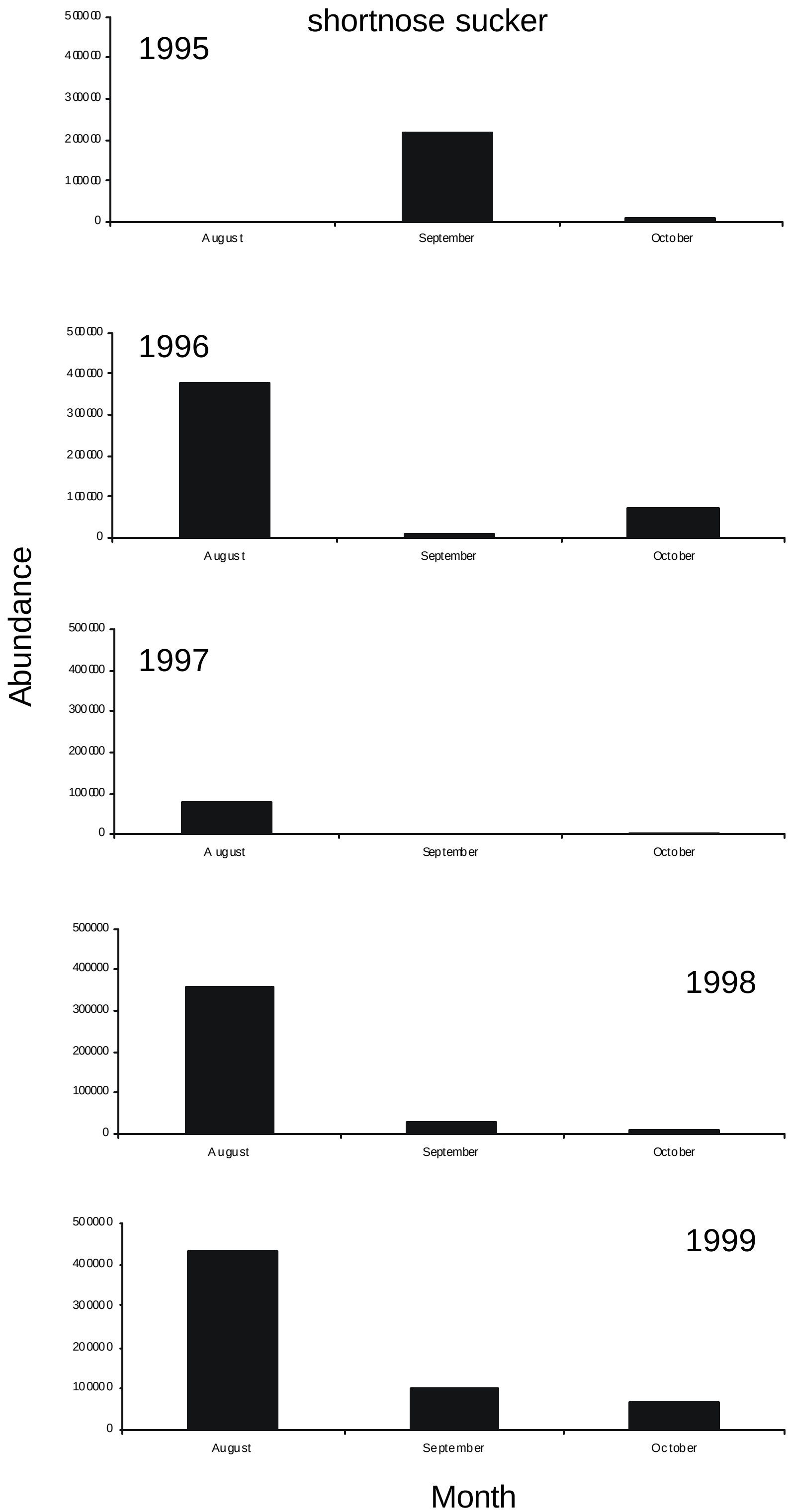


Figure 27. Lakewide population estimates of age 0 shortnose sucker in Upper Klamath Lake by month, 1995-1999. There was no sampling in August 1995.

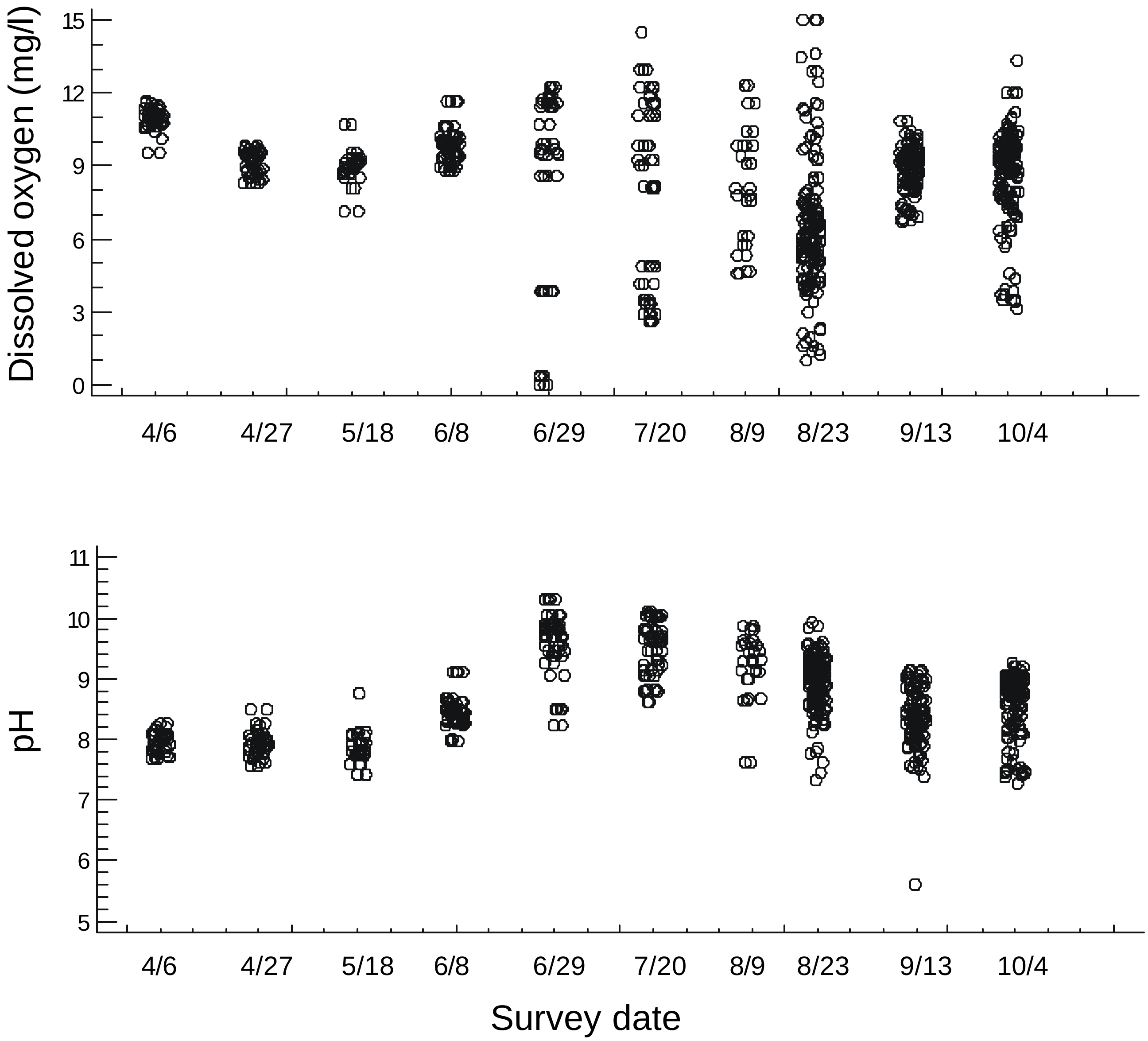


Figure 28. Distribution of dissolved oxygen and pH values during each sampling week in Upper Klamath and Agency lakes, 1999.

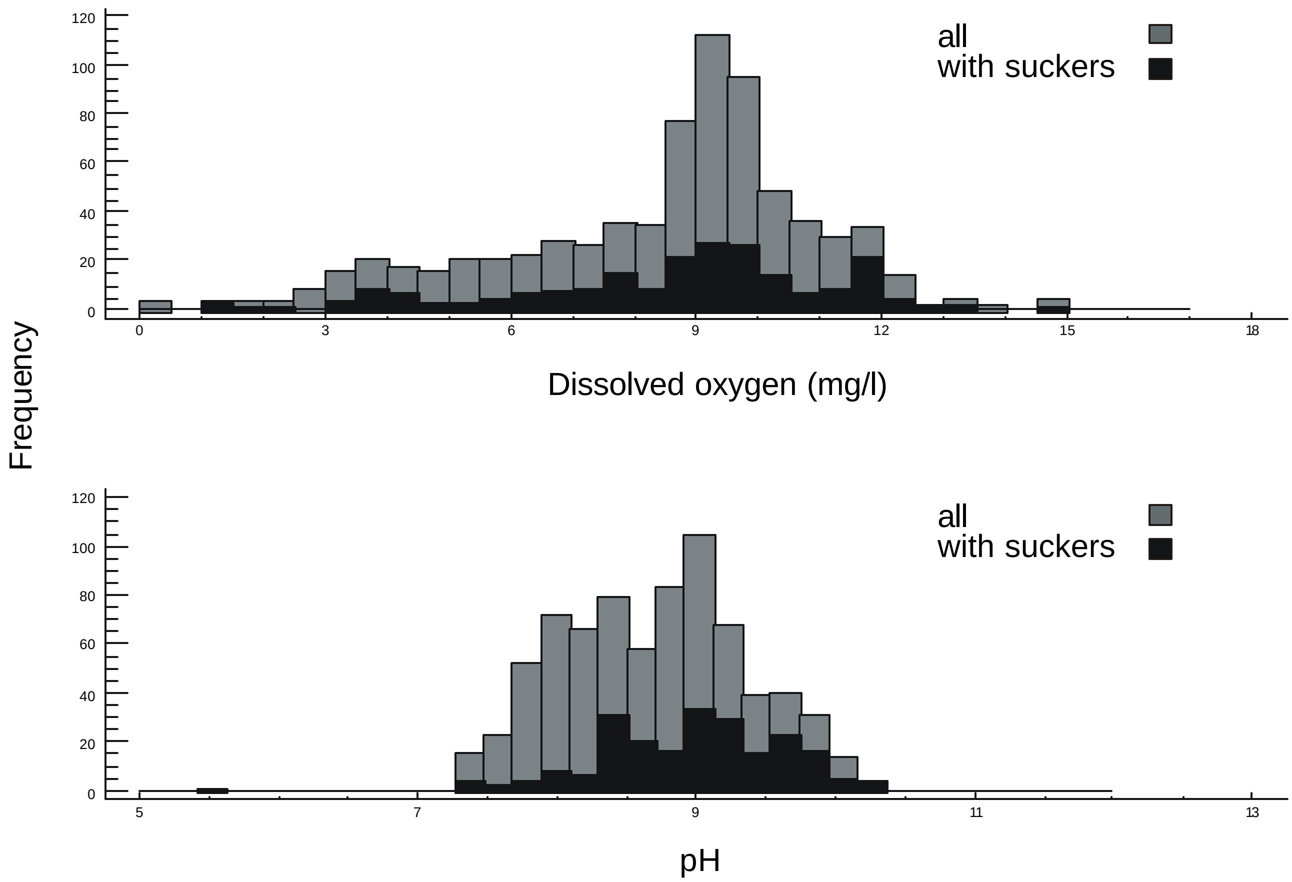


Figure 29. Distribution of dissolved oxygen and pH for all samples (gray) and those samples containing suckers (black) from larval trawl, beach seine, cast net, and otter trawls from Upper Klamath and Agency lakes, 1999.